Oil and Gas Exploration in Nova Scotia 1981·82

Province of Nova Scotia
Department of Mines and Energy

Honourable Ronald Barkhouse, Minister
John J. Laffin, P. Eng., Deputy Minister

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Front Cover Photograph
Jack-up rig "Rowan Juneau" drilling just east of Sable Island, along side the supply vessel the "Balder Hudson". Photo by Captain Larry Wilson.

Back Cover Photograph
The Joseph Howe Building in which the Department of Mines & Energy is located.

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Introduction

Following the first Canadian hydrocarbon discovery in Alberta in 1947, there was intensive exploration in western Canada. In 1959 industry was interested in new sources of energy and the Nova Scotian Shelf was considered to be an exciting prospect. In that year Mobil Oil undertook an air magnetometer survey of the Sable Island area. In the following year they carried out their first seismic program over 4451 km² exploration area on provincial license. In 1963 Shell Canada licensed 80 940 km² from the province and by early 1965 the remainder of the Scotian Shelf was licensed to different companies. In 1971-1973 the area under license extended well down the slope of the Scotian Shelf.

The area licensed in Nova Scotia is approximately 140 835 km² offshore and 26 305 km² onshore, in the Bay of Fundy and Northumberland Strait. Exploratory drilling commenced in 1967 with Mobil Sable Island #1 and resumed in September 1969 when Shell Canada Ltd., contracted the Sedneth 1 semi-submersible drilling vessel to drill on the Scotian Shelf.

To date 74 wells have been drilled in our offshore areas by serveral major companies, including Shell, Mobil, Chevron, Murphy, Union and Petro-Canada. Late in 1972, Anschutz Corporation spudded a 4300 m test in the Cumberland Basin, onshore, and thus began a renewed search for petroleum in the sedimentary environments throughout Nova Scotia. This hole was abandoned at 4536 m in September 1973. Of the 74 wells completed offshore, there have been seven significant shows involving 14 wells. Six development wells were completed on the western tip of Sable Island to assist in defining the limits of the initial noncommercial discovery that was made in 1971. Results were disappointing. The most significant discoveries have been on the Venture Structure approximately 11 km east of Sable Island. Venture D-23 was completed in late May of 1979 to a total depth of 4945 m. This well flowed gas at the rate of 1 132 800 m³/d with associated condensate at the rate of 14 m³/d from 3 zones between 4300 and 4876 m. The first stepout, Venture B-13, (3 km east of D-23) was completed in early June of 1981 to a depth of 5367 m. The results of this well were even more encouraging with a combined rate of gas and crude condensate for the several zones tested reaching 2 124 000 m³/d and approximately 160 m³/d respectively. These tests were all conducted using restrictive choke sizes.

Part I of this booklet provides, a summary of exploration activity to date, and a brief geological summary of the potential hydrocarbon environments.

Part II of the booklet is a summary of how oil is formed, trapped, explored for and produced.

PART I

OIL & GAS EXPLORATION

1· Energy Activity in Nova Scotia

The energy problem facing Nova Scotia, and Atlantic Canada in general, has a few unique features not found in the rest of the country. First, Canada as a whole has oil, natural gas, coal, hydro, and uranium, with the result that crude oil accounts for only about 40% of Canadian energy demand. In contrast, imported crude oil dominates Nova Scotia's energy mix, supplying over 70% of primary energy demand in 1981.

This results in important differences in various sectors. For example, in 1981 about 5% of the electricity generated nationally was from oil while approximately 40% of the electricity generated in Nova Scotia was from **imported oil**. Further, residential, commercial, and industrial space heating and industrial process heating were almost 100% dependent on imported oil. This is in sharp contrast to the situation in Central and Western Canada which have access to secure domestic natural gas, oil and hydro electricity.

This high dependence on oil results in disproportionately high energy costs. Also, the Atlantic region would suffer more than the rest of Canada in the event of an unexpected disruption in oil supply, since it does not have easy access to domestically produced oil.

To correct this situation, Nova Scotia has initiated major thrusts in energy conservation, oil substitution, and emergency preparation. Conservation measures will be particularly important in withstanding oil price increases during the next few years, until we have access to other energy sources, but they will also extend the life of our non-renewable resources. Oil substitution measures will enable us to diversify our energy mix by developing our indigenous energy resources and by obtaining access to resources available from other Canadian provinces. This diversification will involve coal, natural gas, offshore oil and gas, tidal power, and other renewable energy sources.

The world oil situation presents Nova Scotia with problems, but also with opportunities for important economic gains. One of the most exciting opportunities is the development of oil and gas off our shores.

2 · Exploration

"Small quantities of petroleum have been reported to show in several onshore locations. The gypsum of Hants County in the neighborhood of Cheverie contains portions strongly impregnated with it. At Lake Ainslie, Cape Breton, the quantity showing on the surface of the water was so considerable as to have induced exploration. Two bore holes were put down. The first gave indications of oil but was lost at a depth of 656 ft by breaking of the rod which could not be recovered. The second hole was put down to a depth of over 900 ft and gave better promise of oil, yielding, it is said, nearly 992 gal on the bore hole standing for several days. Further work was prevented by the want of funds. Altogether some $20,000 were expended." (Department of Mines Annual Report, 1874).

The search for petroleum in commercial quantities is by no means a new development in Nova Scotia. Events similar to the above have occurred throughout the last 100 years in the onshore sedimentary basins. Numerous holes from 30 m - 4500 m have been drilled and abandoned. A commercial discovery has never been made onshore, although many holes had shows* of oil or gas. Most of the exploration programs were suspended for lack of funds.

As exploration technology advances, new geological theories are developed on the petroleum possibilities in Nova Scotia, new sophisticated seismic techniques are employed to substantiate these theories and drilling programs are designed to prove the existence of any oil or gas deposits.

Geological, geophysical and drilling programs recently completed or in progress by several companies will hopefully lead to Nova Scotia's first commercial oil and gas production onshore.

Chevron Canada in partnership with Irving Oil completed an extensive seismic program on the more than 16 188 km^2 they have under license and on August 10th, 1981 spudded their first well, Chevron/Irving Scotsburn No. 2, at West Branch, River John, Pictou County (Figure 2). This well had a total depth of 2638 m.

The current drilling phase of offshore exploration began in 1967 when Mobil Oil drilled a 4500 m hole on Sable Island. Two years later Shell Canada began an extensive drilling program in conjunction with marine seismic research. To date 74 wells have been drilled offshore Nova Scotia (Appendix A). Land based rigs were used for nine wells on Sable Island and semi-submersibles, jack-ups and shipshape rigs for the 65 completed offshore (Figures 2 and 3).

Drilling equipment used for onshore exploration is usually imported from Western Canada or Ontario as it is readily adaptable to the prospective locations (Figure 2). Originally a land based rig was used for the Sable Island wells, however, because of the unique shape and size of the Island, the shifting sand problems and structural configuration of the underlying sediments, Mobil mounted a special converted platform rig on 2 m piles at the Western tip of the Island which drilled a series of six holes in a divergent circular pattern.

In 1969, Shell contracted a semi-submersible rig, the Sedneth 1, a Dutch unit that had been drilling in Norwegian waters. At that time the first semi-submersible was being built at the Halifax Shipyards primarily for use in Atlantic offshore. The cost of these rigs has increased with the increased cost of new materials and construction. In September 1978 Sedco 709 was launched at a cost of about $80 million compared with $17 million for Sedco I in 1971 and $13 million for Sedco H, built in 1970. In 1981 a semi-submersible capable of drilling offshore Nova Scotia would have a price tag of $140 million.

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* It might be noted that in our term a "show" of oil or gas means evidence of oil or natural gas encountered while drilling. The degree of importance that is placed on a showing of oil or gas depends on many factors including the types of sediment, porosity, permeability, depth encountered, thickness and extent of show, and how it reacts to various quantitative and qualitative tests carried out from the surface and on the samples obtained.

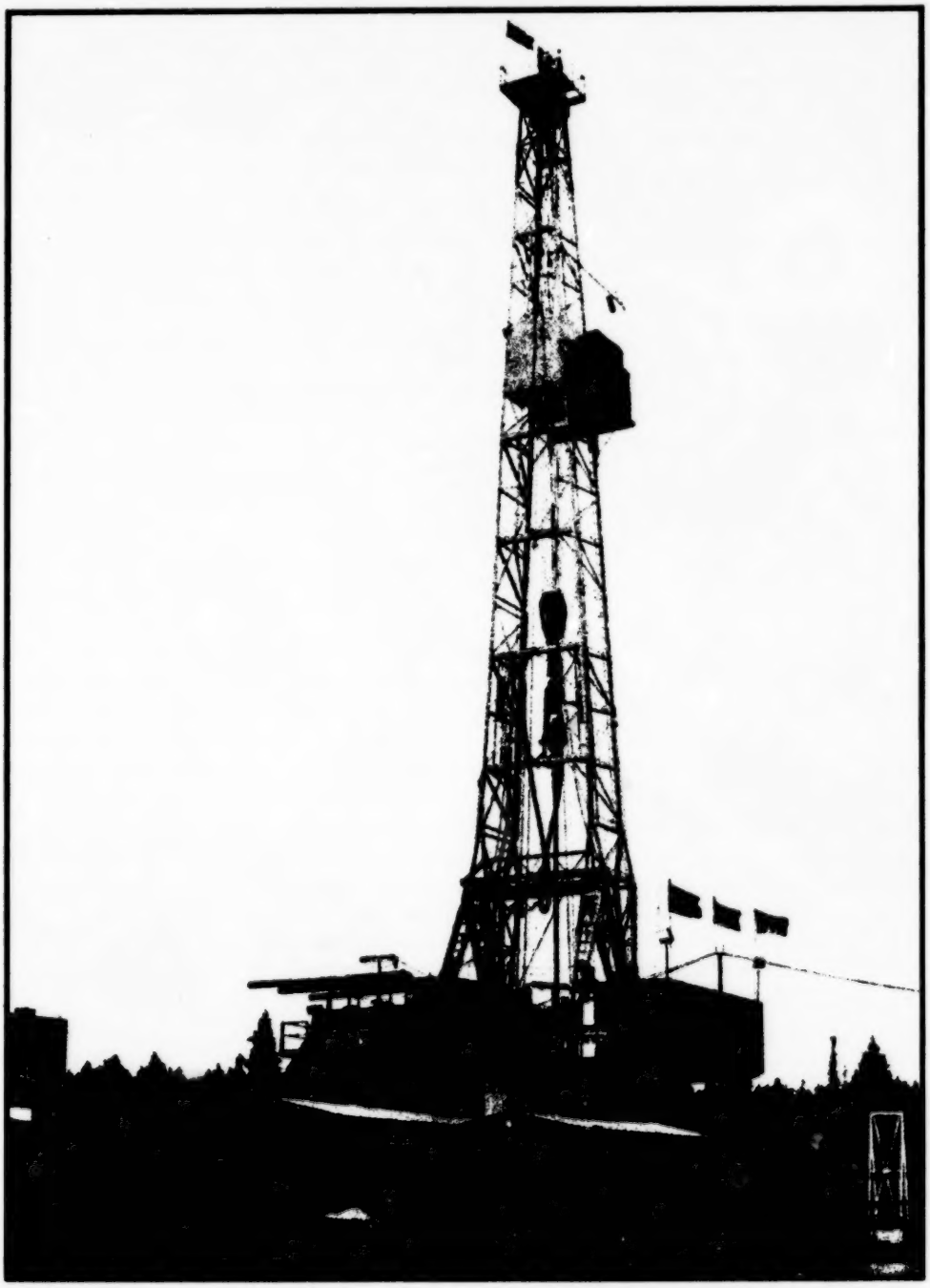


Figure 2. Regent drilling rig in Scotsburn, Pictou County.

The rigs are designed with the North Atlantic climate in mind, and have a 200 m to 2000 m water depth drilling capacity. They are designed as a "Packaged Unit" and only consumable materials have to be delivered to the rig on location. The latest ideas in safety design, environmental care and pollution free operation are integral parts of each vessel. A service boat is required to stand-by the drilling rig at all times (Figure 4). The drilling rigs are served continuously, weather permitting, with new materials and supplies from shore based facilities where warehouses and supply depots have been established (Figures 5 and 6).

The 74 holes completed covered a broad range of geological targets and were dilled in an area that extends from 100 km south of Shelburne on the southwest to 40 km north of Sydney on the northeast. Oil and gas shows were encountered in clastic rocks of Cretaceous age, clastic and carbonate rocks of Jurassic age, and the offshore Sydney area in Carboniferous age sedimentary rocks (Table I, Geological Time Scale).

Recent geophysical surveys, interpretations of drilling results and regional correlations indicate several exciting geological concepts. These include a geopressured zone in proximity to Sable Island, a Shelf edge carbonate bank that extends from Georges Bank through to the eastern side of the Scotian Shelf and updip stratigraphic traps, which make up large untested structures that could contain significant volumes of hydrocarbons. For these reasons we believe the Scotian Shelf may well become one of the major oil and gas producing areas in Canada (Figure 7).

The most encouraging offshore results to date are outlined here and the well locations are shown in Figure 8 (a).

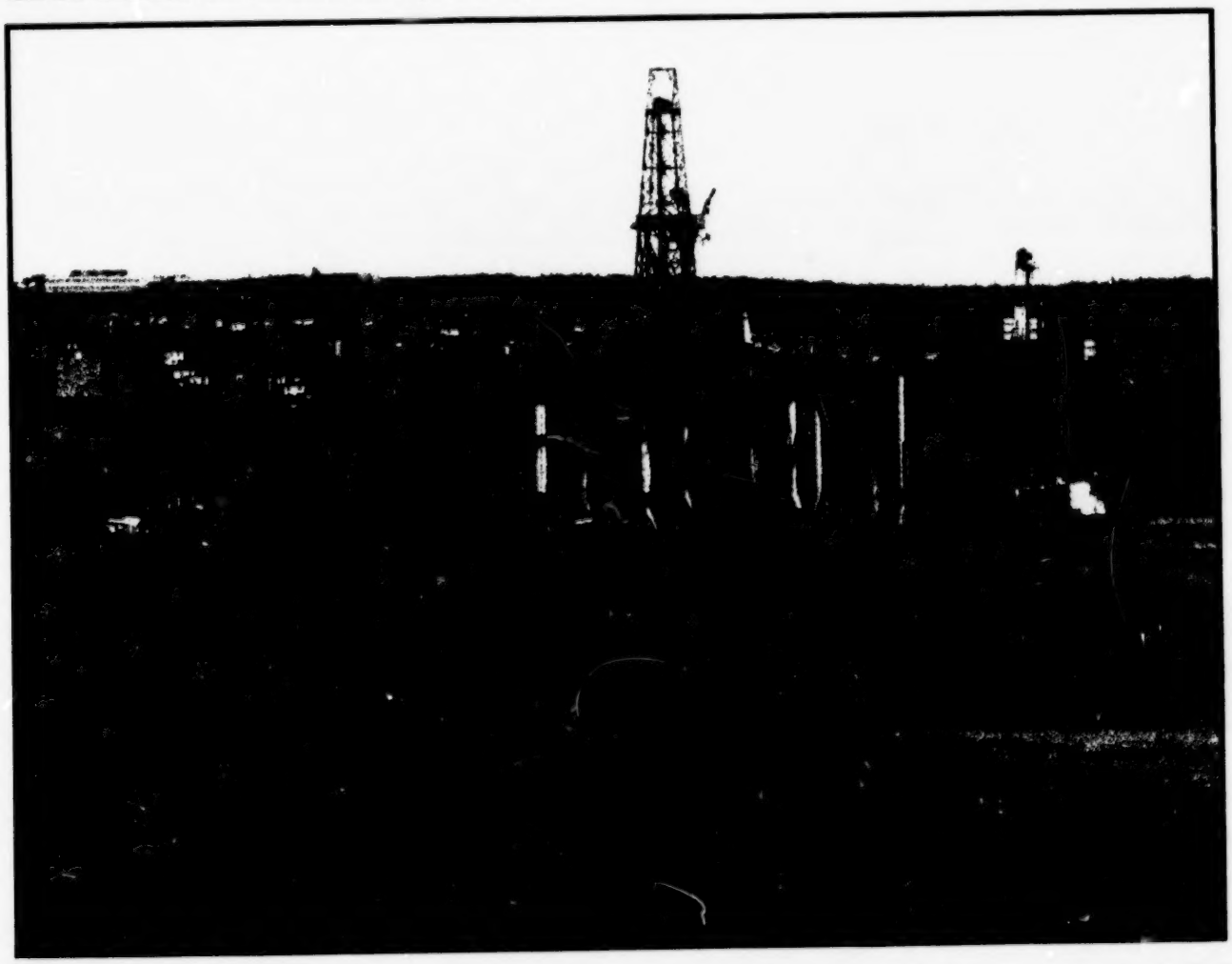


Figure 3. The Bowdrill I semi-submersible, arrived in Halifax on November 9, 1981. It is owned by Bow Valley Offshore and is contracted by Petro-Canada.

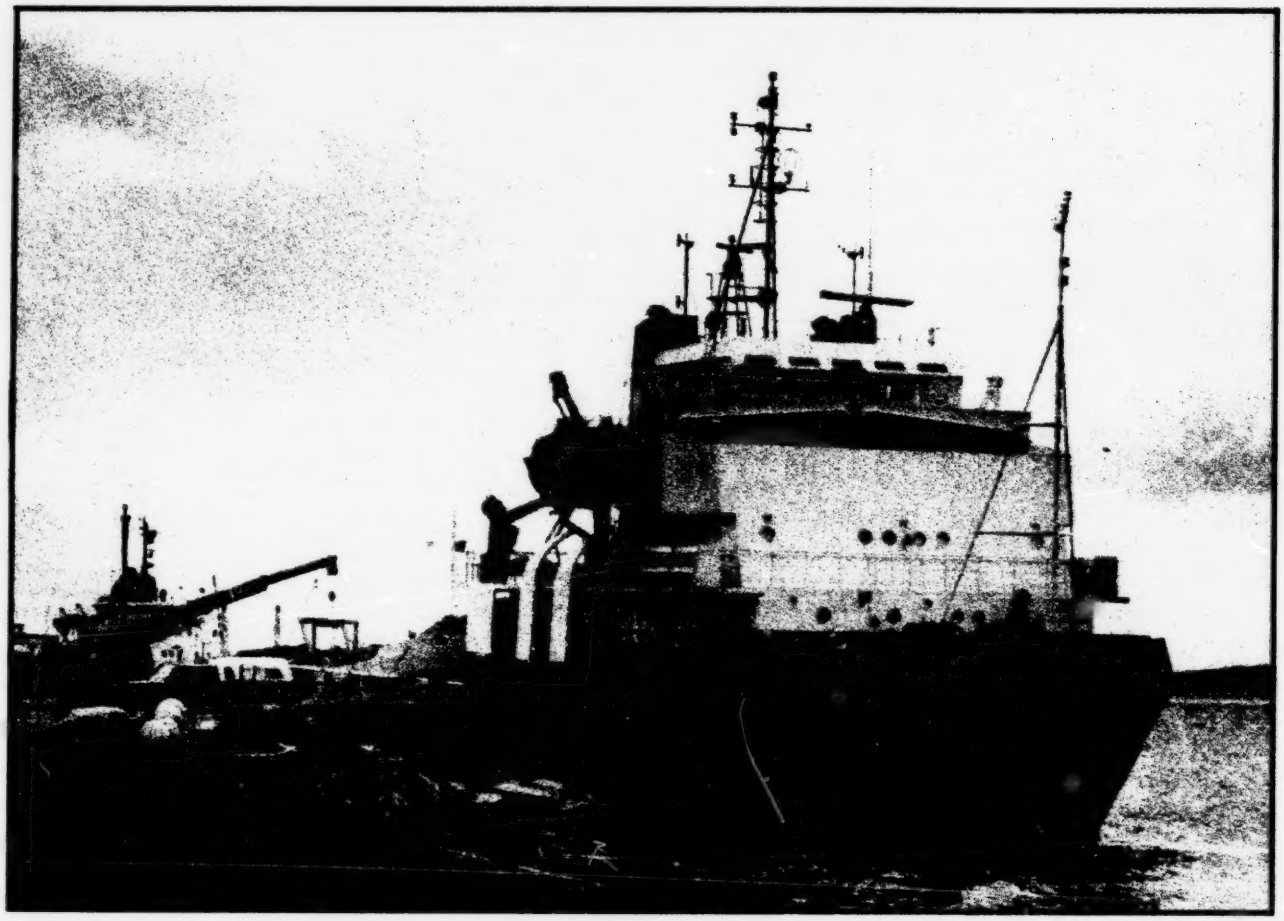


Figure 4. Supply vessel being loaded at a Dartmouth dock site.

Significant Shows (Possibly Commercial)

1. Venture Structure (Figure 8 (b)) is located 12 km east of Sable Island. One hole, D-23, completed in late May 1979 to 4947 m encountered several gas-bearing sandstones between 4328 m and 4937 m that flowed gas from 3 zones at a combined rate of 1 132 800 m^3/d and 80 m^3/d of condensate. Another well, B-13, 3 km southeast of D-23, was completed in early June of 1981 to a total depth of 5364 m. The combined flow rate for the tested zones reached 2 024 000 m^3/d and approximately 214 m^3/d of condensate. A third well, B-43, 3 km west of D-23, recently attained a total depth of 5872 m. No final estimate of reserves can yet be calculated although the completion of the B-43 well, will lead to a greater certainty that significant hydrocarbons exist on this structure.

2. Thebaud Structure is located 7 km southwest of the western end of Sable Island. Two holes have been completed. P-84 produced 30 to 40 thousand m^3/d gas from each of several zones between 2740 and 3600 m. I-94 drilled approximately 1 km southwest of P-84 did not encounter the same pay sections uphole. It did, however, find several significant gas zones below 3600 m that correlate with the discovery well. No firm estimate of potential reserves can be calculated and additional drilling is necessary to confirm the presence of a major hydrocarbon reservoir.

Significant Shows (Noncommercial Structures)

1. West Sable has seven holes completed. The structure, created by a salt piercement structure at 3650 m was found to be severely faulted and the reservoirs discontinuous. Estimated reserves of oil and gas do not warrant development at this time.

2. Cohasset is located 48 km west of the western end of Sable Island. Two wells were completed on the structure. D-42 produced 159 m^3/d oil from 37 m of pay. A stepout well, P-42, 1 km northwest was dry and did not encourage further exploration.

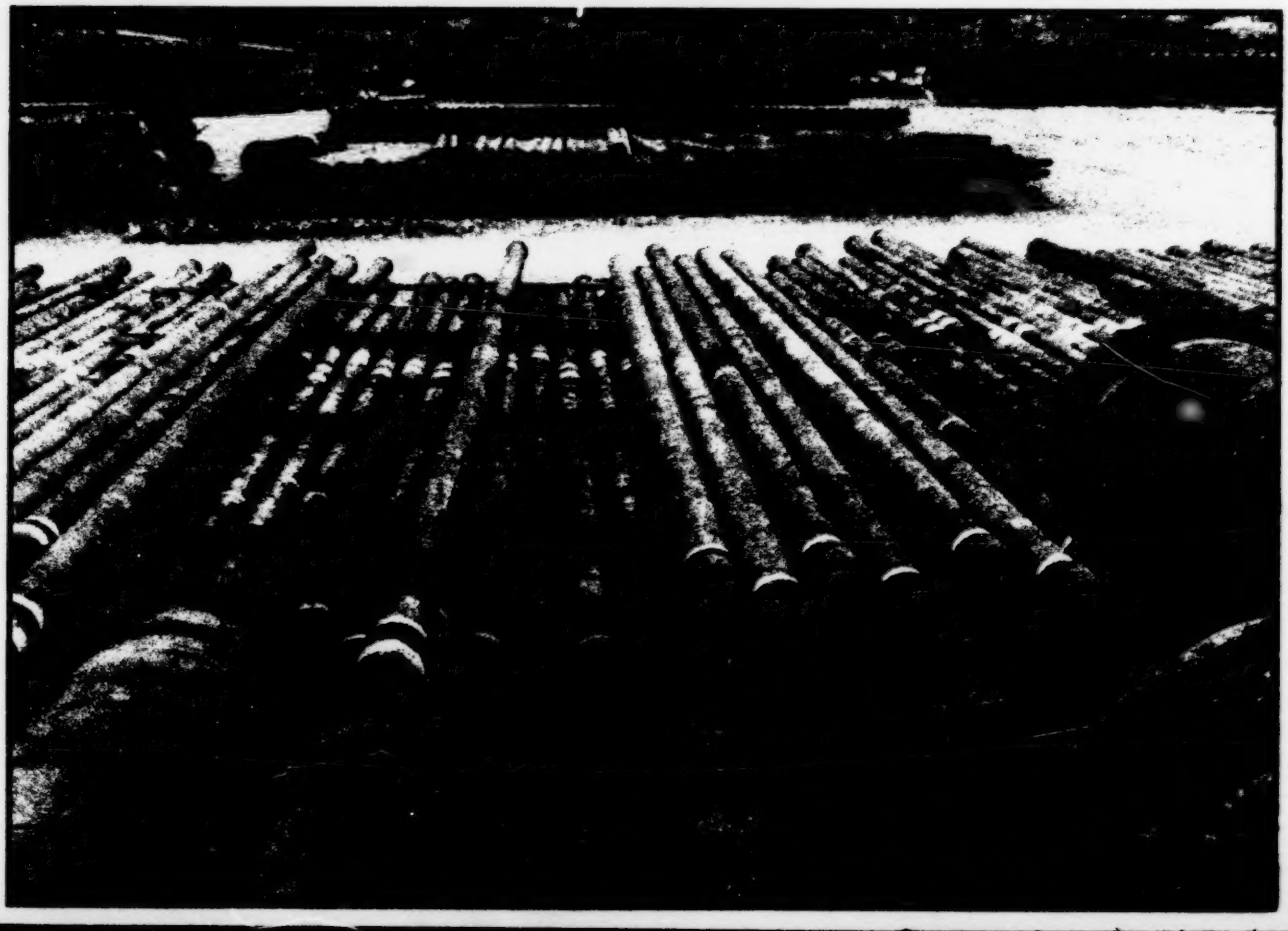
3. Citnalta is located 16 km northeast of eastern Sable Island. One hole, I-59 was drilled. Gas condensates were tested from three thin zones at the combined rate of 283 200 to 339 840 m^3/d. Additional exploration is needed on this discovery.

APPROXIMATE TIME (10^6 yrs)		PERIOD	FORMATION	MEMBER	DOMINANT LITH.
CENOZOIC		QUATERNARY	SABLE ISLAND		SAND & GRAVEL
			LA HAVE		CLAY
			SAMBRO		SAND
			EMERALD		SILT
			SCOTIAN SHELF		GLACIAL DRIFT
	1.5	TERTIARY	BANQUEREAU		MUDSTONE
MESOZOIC	65	CRETACEOUS	WYANDOT		CHALK
			DAWSON CANYON	LST. MARKER	SHALE
			LOGAN CANYON		SANDSTONE & SHALE
				SABLE SHALE	SHALE
					SANDSTONE & SHALE
			NASKAPI		SHALE
	136		MISSISAUGA	LST. MARKER	SANDSTONE
		JURASSIC	MIC MAC	VARICOLORED SHALE	CALCAREOUS SHALE
			VERRILL CANYON		SHALE
			ABENAKI	BACCARO	LIMESTONE
				MISAINE	CALCAREOUS SHALE
				SCATARIE	LIMESTONE
	175	LOWER JURASSIC –TRIASSIC	MOHAWK		SANDSTONE & SHALE
			IROQUOIS		DOLOMITE
	190-195		ARGO		SALT

Table I. Geological Time Scale, with Formations occurring offshore Nova Scotia.

Figure 5. Offshore drilling supplies in Dartmouth.

Figure 6. Pipeyard in Dartmouth.



4. Penobscot is located 22 km north of the western end of Sable Island. Several thin oil zones (untested) were encountered between 300 and 3300 m. A second well, B-41, showed the equivalent zones to be water-bearing or discontinuous.

5. Primrose is located 80 km east of eastern Sable Island. Three holes were completed. Gas was tested in three zones. Further exploration may be done in this area.

6. Onondaga is located 22 km south of the west Sable structure. Four holes encountered significant quantities of gas. The first well, E-84, showed the most encouragement. More detailed exploration is necessary on this structure.

7. Eagle is located 20 km southeast of the eastern end of Sable Island. Gas shows occurred while drilling. Additional exploration is possible.

Future Plans

Mobil Oil recently completed drilling a second step-out well, B-43, on the Venture Structure east of Sable Island, at the beginning of January 1982. Total depth reached was 5872 m and production drill stem testing is being carried out at present. The first three test results indicated two additional reservoirs below those tested on the initial discovery D-23 and first step-out B-13. Production testing of the well should be completed by mid April 1982, when the rig will be moved to a new site, 10 km south, named South Venture O-59.

The well was drilled by the Rowan Juneau, a jack-up rig modified to meet the requirements of the northern drilling environment as well as a 103 420.5 kpa (15 000 psi) BOP stack to control pressures encountered in the drilling program.

Mobil has a second jack-up rig, the Zapata Scotian, recently built and towed from Singapore. It will be on location very shortly, ready to commence drilling at the site Olympia A-12, just north of the eastern tip of Sable Island. Mobil has exploration plans to have a continuous drilling program in the Sable Island area for the next three to five years.

Petro-Canada is drilling their first well as operator on the Scotian Shelf, named Banquereau C-21, approximately 100 km east of Sable Island. The present depth (end of March 1982) of the hole is 3 950 m.

Shell Canada, in conjunction with its partners CDC, and Norcen have announced a four well program on the Scotian Shelf starting in the fall of 1982.

Onaping-Scotia Resources have announced a well to be drilled on their south Sable Block by Shell Canada in 1983. Petro-Canada, Hudson's Bay, Inco, Onaping, Chevron and Texaco have all completed extensive seismic programs and following interpretation of results, will undoubtedly be looking for rigs.

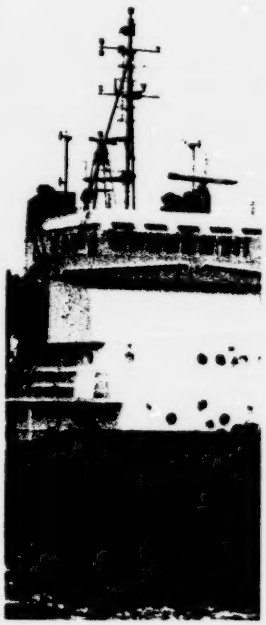
As previously mentioned, Chevron has taken a strong approach to exploration for petroleum in the Bay of Fundy, Northumberland Strait and onshore New Brunswick, Nova Scotia and Prince Edward Island. Chevron in partnership with Irving completed their Scotsburn No. 2 hole in Pictou County in November 1981, to a total depth of 2638 m.

Several smaller companies have acquired oil and gas licenses in other onshore areas and are completing geological programs, prior to seismic and hopefully drilling programs.

It appears that a new aggressive exploration program is underway and we are optimistic that commercial quantities of hydrocarbons will be found, production will commence and oil and gas activity will continue for many years to come.

3 · Geological Setting

Onshore



Exploration companies for over a century have tried to interpret the geological history of the extremely varied sedimentary basins in the onshore and near shore areas of Nova Scotia. These basins which contain sediments suitable for the generation and trapping of hydrocarbons vary in thickness from a few hundred to thousands of metres which include sandstones, siltstones and shales from Pennnsylvanian through Lower Mississippian in age. The Lower Mississippian is also noted for its thick sequences of evaporites and carbonates.

As can be seen from the license map (Figure 1, centrefold) the areas of interest are extensive and include the Minas Basin area, the Cumberland Basin, the Stellarton Gap-Pictou Basin, the Antigonish Basin, the Inverness-Mabou sub-basin, the Lake Ainslie area, the Bras d'Or/River Denny's area and the Sydney sub-basin.

From extensive geological mapping, geophysical surveys, diamond drilling and deep drilling for petroleum, the basins have been found to be complicated by the nature of deposition, age of sediments, erosion, structural movements contemporaneous to and following deposition, flowage of evaporites and many more stratigraphic and structurally complex geological problems. Dr. W.A. Bell's report "Petroleum Possibilities in Nova Scotia" gives a more detailed geological discussion on the various basins.

Numerous oil and gas showings have been located throughout the province by drilling or surface seepage and this has led petroleum geologists to recognize the potential of the area and to realize that the sediments are capable of generating hydrocarbons.

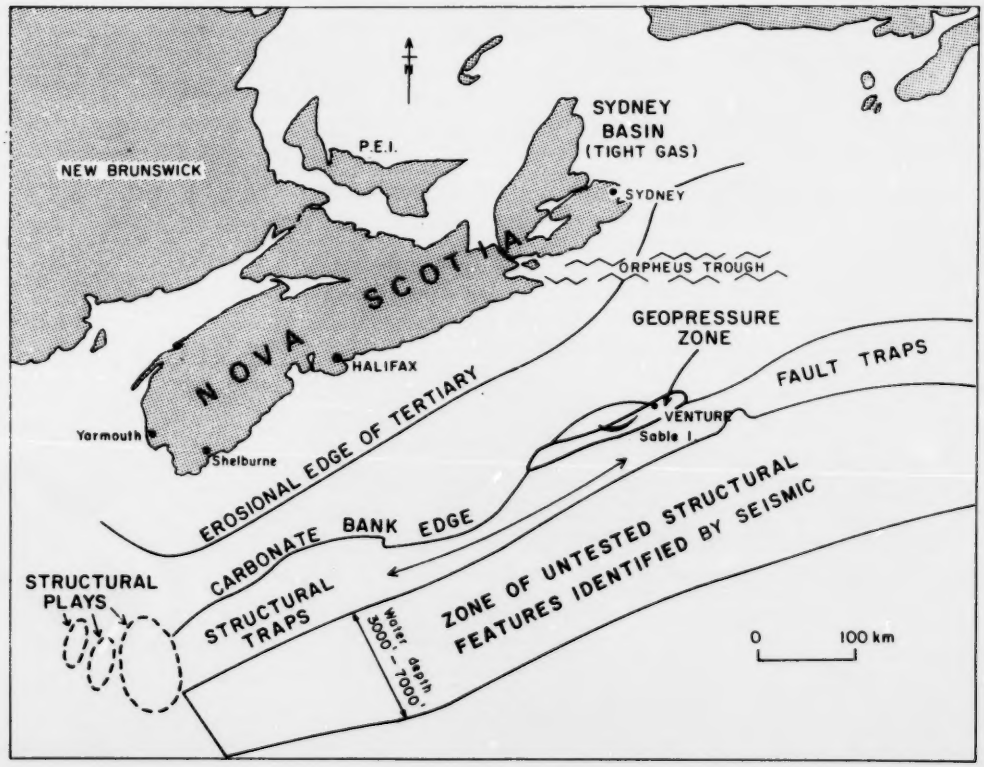


Figure 7. Geological Trends "Scotian Shelf".

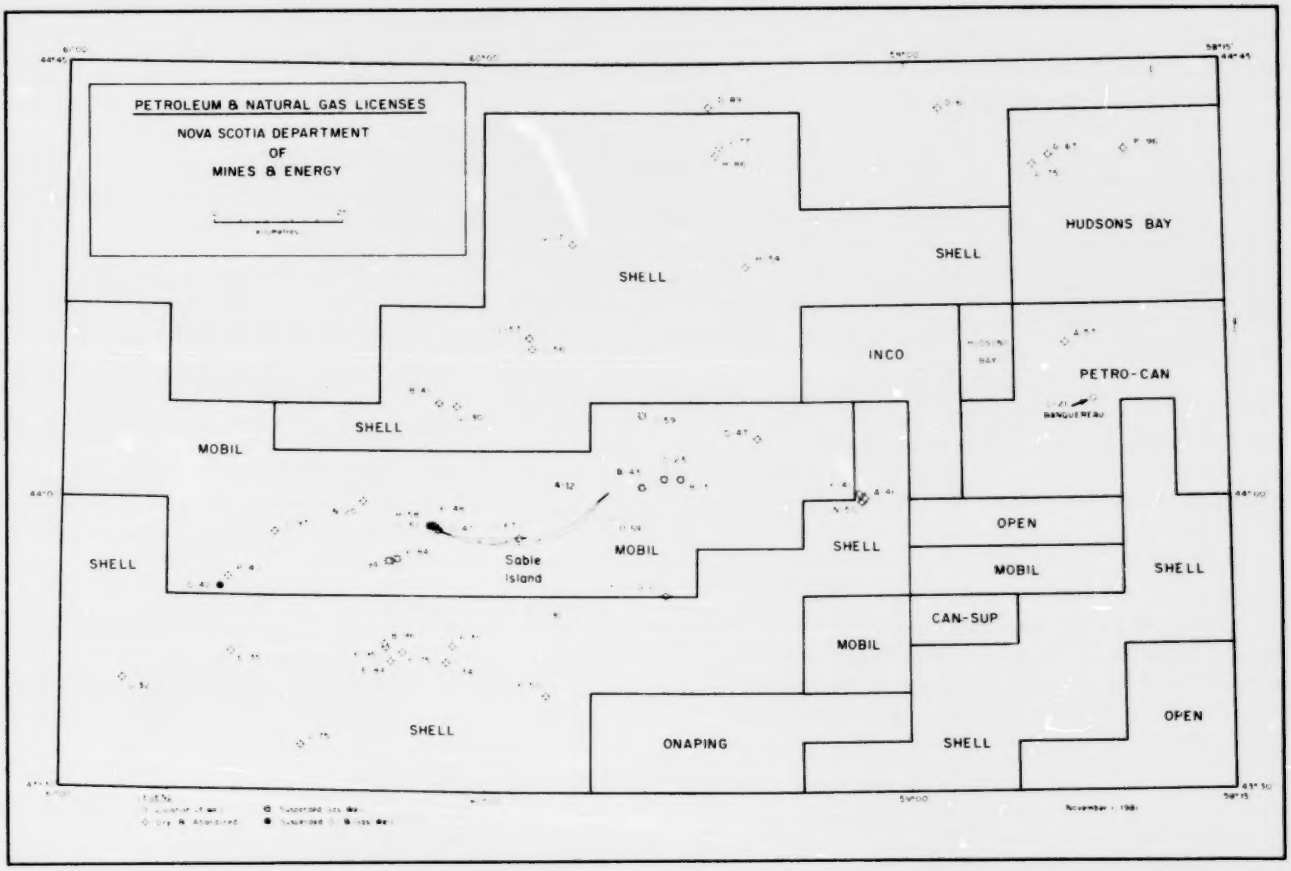


Figure 8(a). Well Locations in the Sable Island Area.

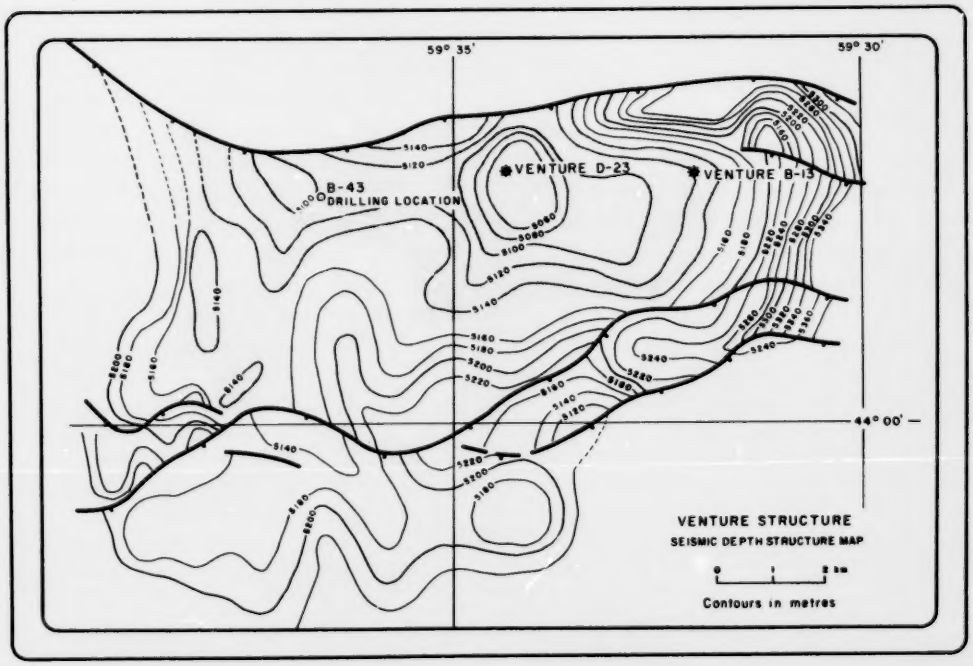


Figure 8(b). Venture Structure (After Meneley, 1981).

Each basin mentioned above is considered for detailed exploration with three main criteria in mind: (1) **source rocks** — rocks that at one time in geological history were capable of generating hydrocarbons; (2) **reservoir rocks** — sediments that have pore spaces adequate for storing or holding quantities of petroleum sufficient for commercial development; and (3) **traps** — rock configuration that, through deposition of sediments or structural movement within the basin, have created a trap for the hydrocarbons.

Oil has been found in similar geological environments in other parts of the world and with the world shortage in energy, a renewed effort is being made to find economical quantities of oil in Nova Scotia.

Offshore

The offshore areas of Nova Scotia that have thicknesses of sediments capable of producing hydrocarbons are very extensive and, as can be seen from the licensing map, they completely surround the province. On the Scotian Shelf, potential sediments extend east and west beyond the geographic extremities of the province and over two hundred miles seaward. Drilling to date has indicated sediments younger in age and much more widespread than those encountered onshore.

All of the 140 835 km² now held under offshore licenses have sediments favourable for the trapping of petroleum. Generally, the shelf area contains thick sequences of mudstone, sandstone, shale, chalk and limestone varying in thickness and depositional characteristics. Geophysical surveys indicate that the Sable sub-basin may contain a thickness of sediment up to 12 000 m.

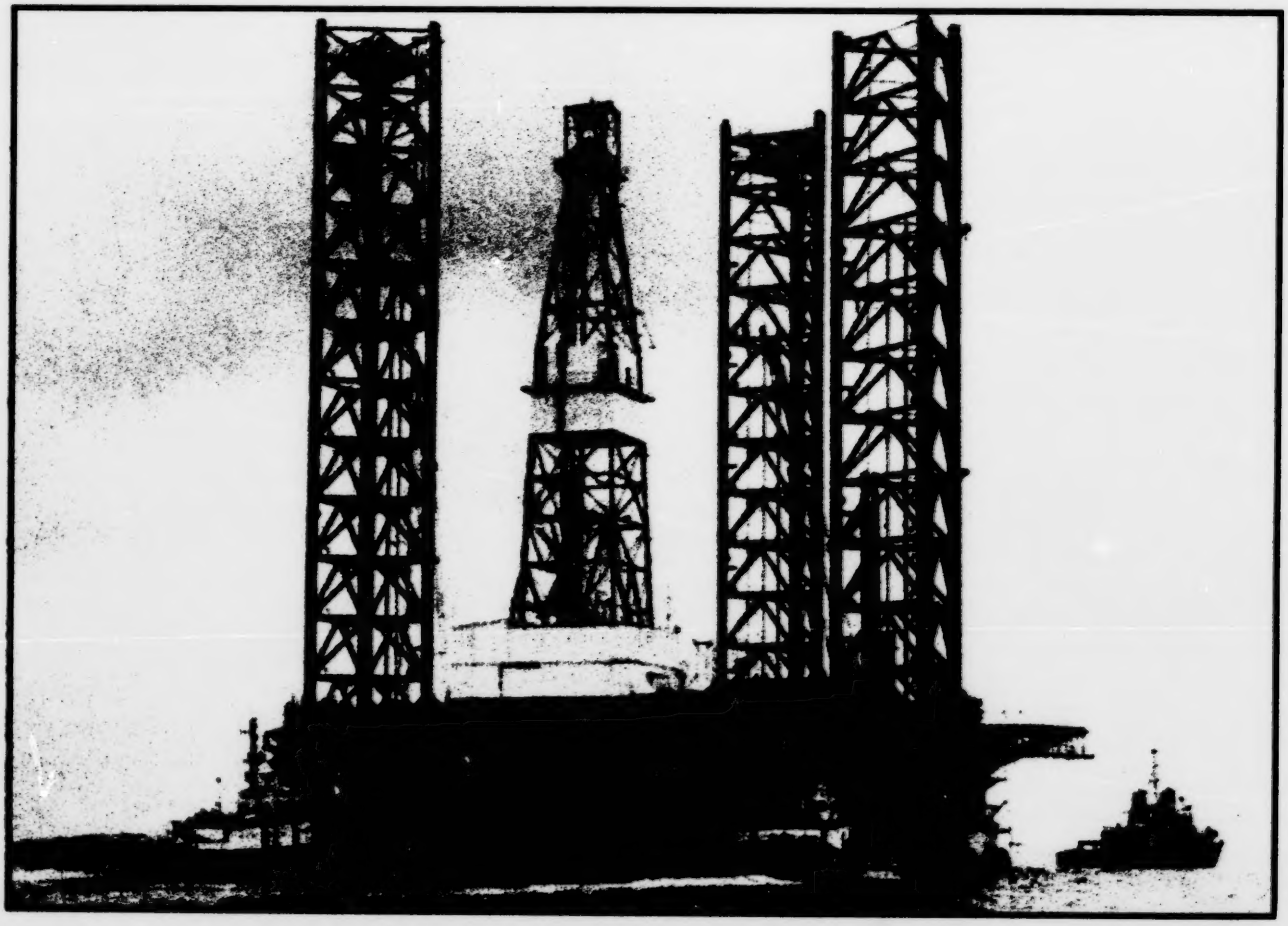


Figure 9. Zapata Scotian contracted by Mobil Oil to drill on Scotian Shelf

The deepest hole to date on the Scotian Shelf has been Mobil Pex Venture B-43 that bottomed in calcareous shale at 5872 m. The oldest mapped sedimentary rocks on the Scotian Shelf have been evaporites, thought to be Upper Triassic in age. The regional cross-section shown in Figure 10 extends across the Shelf in the vicinity of Sable Island. The sedimentary section comprises a seaward thickening wedge of Jurassic to Tertiary sediments. Initial sediments, overlying a pre-Carboniferous basement of Devonian granites and Cambro-Ordovician meta-sediments, are continental clastics, evaporites and dolomites characterizing the prerift and rifting sequences. These are followed by a major Jurassic transgression with the deposition of open-marine carbonates and their clastic equivalents. The Late Jurassic and Lower Cretaceous is characterized by a regressive wedge of deltaic clastics built up along the continental shelf and slope, within which are transgressive and regressive cycles.

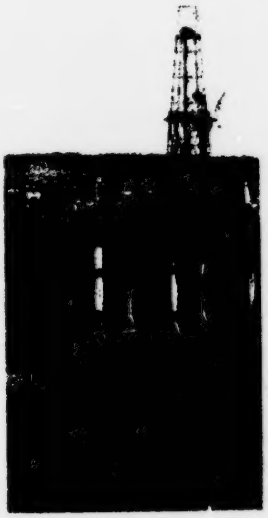
The Jurassic and early Cretaceous section is of prime interest in the hydrocarbon potential of the Scotian Shelf. This section includes the shelf margin, Baccaro carbonate front which extends along the entire Scotian Shelf. In the back reef position to this carbonate there is a predominately clastic section with some interbedded carbonates which are called the Mic Mac Formation and extend from the shelfward hingeline of the prerift salt basin to the Baccaro carbonate front. In the vicinity of Sable Island, in the depocentre and focus of maximum sedimentation on the Scotian Shelf, the clastic influx passed over and through the reef complex to deposit clastics in front of the Baccaro carbonate.

Throughout the remaining Cretaceous time a coarse clastic section called the Missisauga Formation was deposited over the shelf, and across the older Baccaro carbonate. Seaward of the reef the coarse sands become more interbedded with shale and finally pass to shale.

In late Cretaceous time a widespread chalk formation was deposited which was overlain by the seaward prograding Tertiary clastics. An unconsolidated to consolidated sequence of mud and sand mapped as Recent forms the remainder of the column.

The Abenaki and Sable sub-basins form an important re-entrant into the regional shelf trend and a centre of maximum deposition which is critical to the generation of oil and gas.

The structures which have been tested so far are either salt diapirs such as the original Mobil oil and gas discovery on Sable Island, or down to basin fault structures such as the Venture gas discovery. The hydrocarbons found to date are essentially confined to the centre of maximum deposition which extends through the Abenaki and Sable sub-basins.



Hydrocarbons have been found in reservoirs ranging from Late Cretaceous to Upper Jurassic age. Exploration has been frustrating because in many cases the hydrocarbons have been found in thin individual pay sands with each zone overlying water. As a result, a slight loss of elevation in a follow-up well has resulted in loss of the entire oil and gas pay. Alternately, the sand distribution has been erratic and pay sands present in a discovery have been absent in follow-up wells. The piercement salt domes have proven to be completely faulted and the hydrocarbon distribution has been complex as a result. The most consistent and, so far most successful, exploration play has been found along the basin fault structural trend found extending through the Sable Basin where the fault structures lie parallel with, but seaward from, the Baccaro carbonate front. To date, gas and condensate have been found in these reservoirs. The reservoirs are in the interbedded sand-shale section below the predominately coarse clastic Missisauga Formation. This section is characteristically geopressured but the sands do correlate laterally, and individual sands appear to have sufficient areal extent to provide commercially attractive reservoirs. (Reference for previous discussion — R. Meneley, 1981).

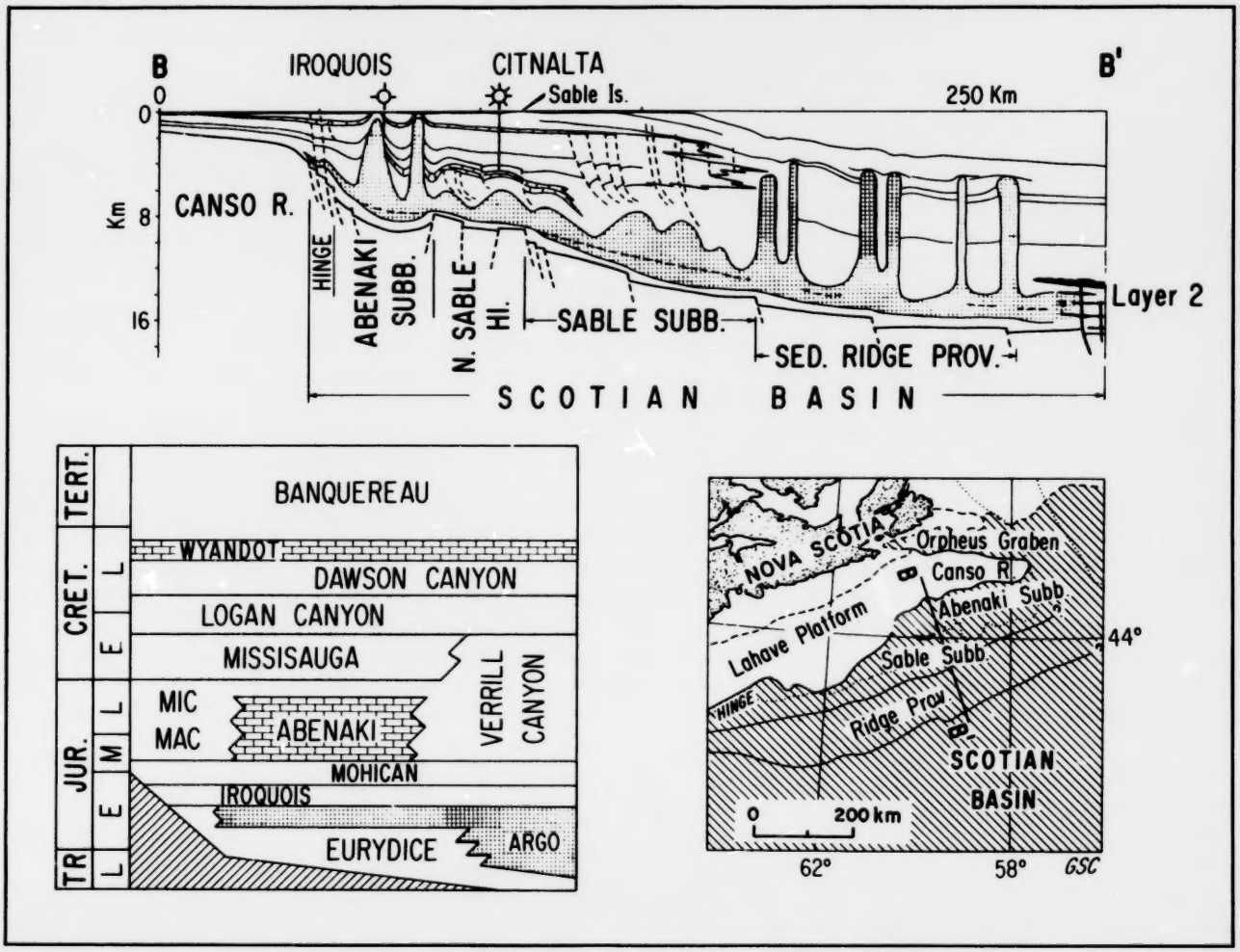
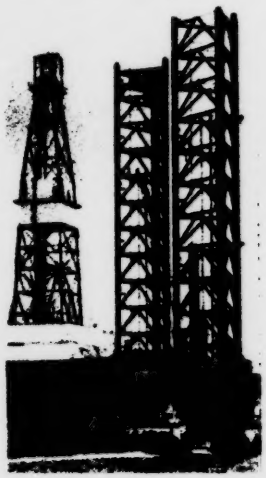


Figure 10. Cross-section of Scotian Shelf (After J. Wade, 1980).

North of the Scotian Shelf and east of Cape Breton, the offshore sediments again are older. The areas that have been drilled in the offshore Sydney Basin identified sediments that are an extension of the onshore Sydney Basin and thus are from Pennsylvanian through Mississippian in age. The Magdalen Islands Basin, south and west through the Northumberland Strait and including northern Nova Scotia, has a potential to contain a thick Carboniferous sequence with many related evaporitic structures. This was evidenced by the Hudson Bay F-25 well that bottomed in Lower Mississippian at a depth of 3010 m. A second well, Hudson's Bay E-49, had a good show of natural gas and has prompted exploration companies to continue their search in this environment. Two subsequent wells drilled in this area were dry.

4 · The Role of the Department of Mines and Energy



The Agreement between Canada and Nova Scotia on Offshore Oil and Gas Resource Management and Revenue Sharing, signed on March 2, 1982, establishes the organizational arrangement through which Nova Scotia can influence all aspects of oil and gas development activity in Nova Scotia's offshore.

The Nova Scotia Petroleum Directorate is the Agency designated to coordinate participation by the Nova Scotia Government in the implementation of the Agreement. The Petroleum Directorate, based in the Department of Mines and Energy, will consist of a small group of professionals with expertise in the offshore oil and gas industry. This group will advise the Nova Scotia members of the Canada—Nova Scotia Offshore Oil and Gas Board on key issues such as exploration agreements, provisional leases and production licenses. The Directorate will be the lead agency within the Provincial Government in dealings with Canada Oil and Gas Lands Administration (COGLA) and the oil industry, handling operational activities directly (e.g. drilling programs and safety procedures), and playing a liaison and coordination role in issues involving other departments of the Provincial Government (e.g. economic benefits and the fishery).

PART II

OIL & GAS INFORMATION

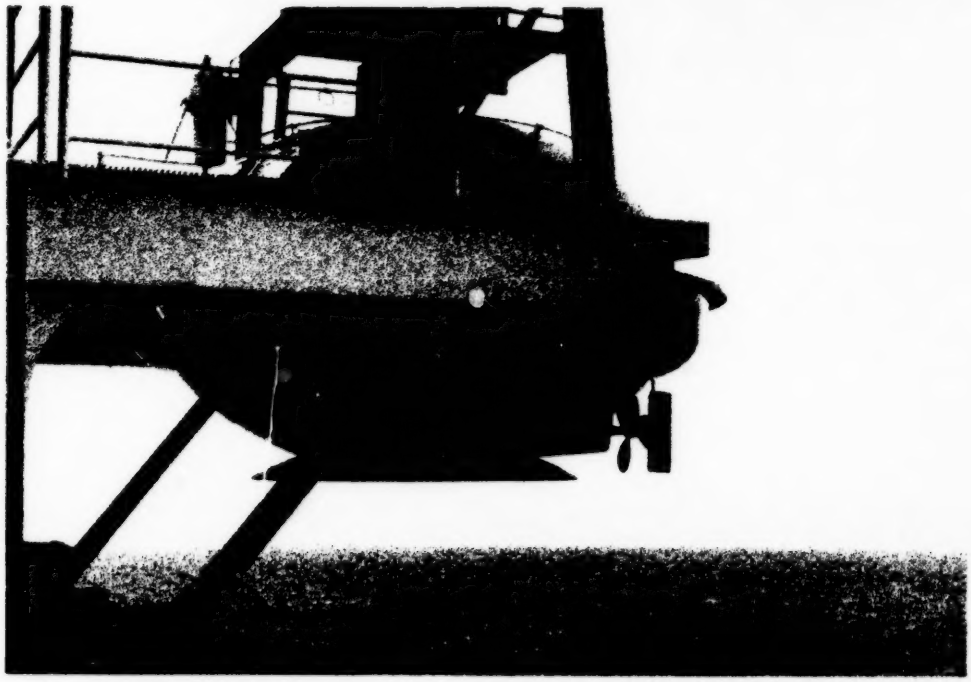
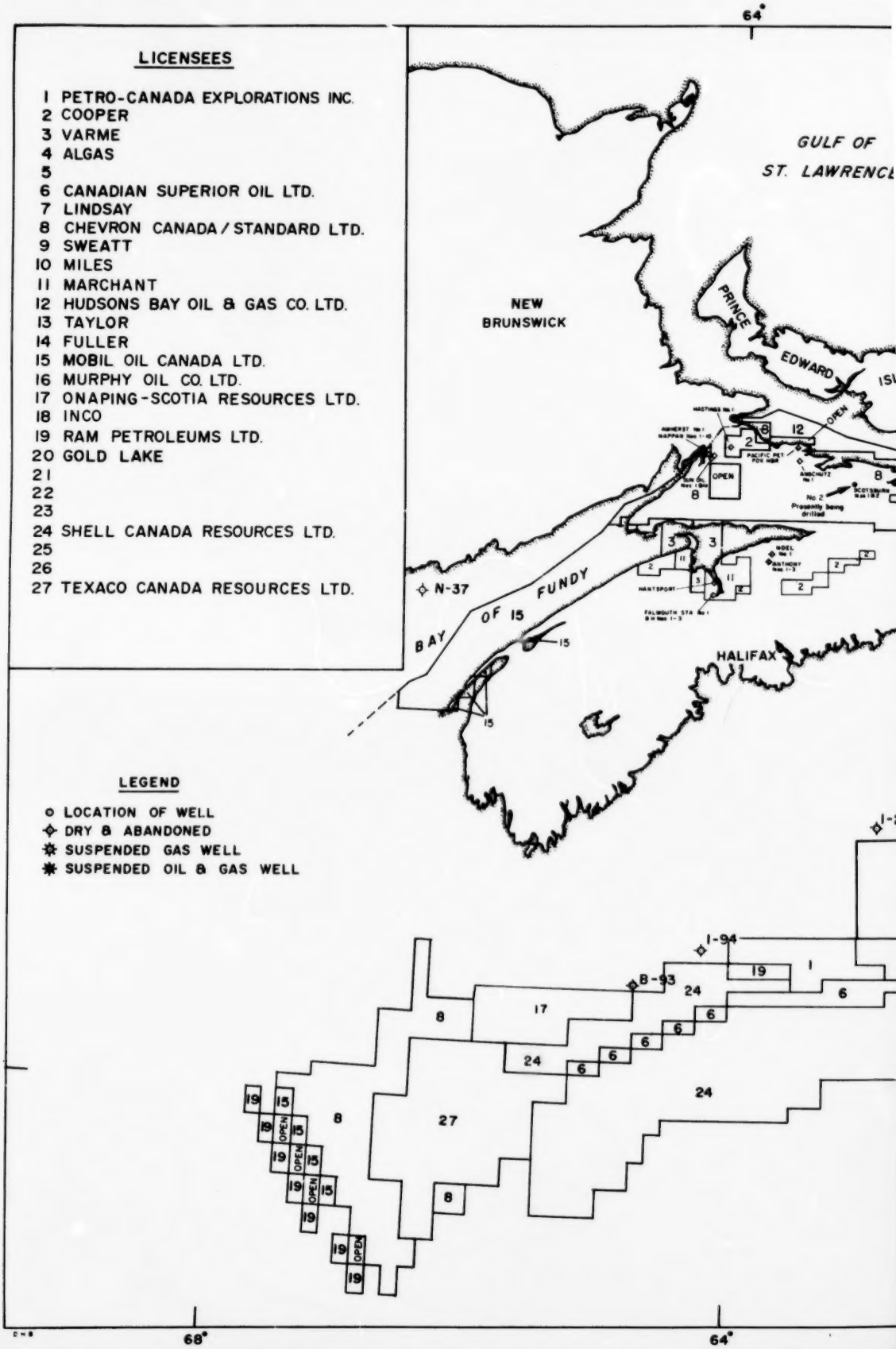
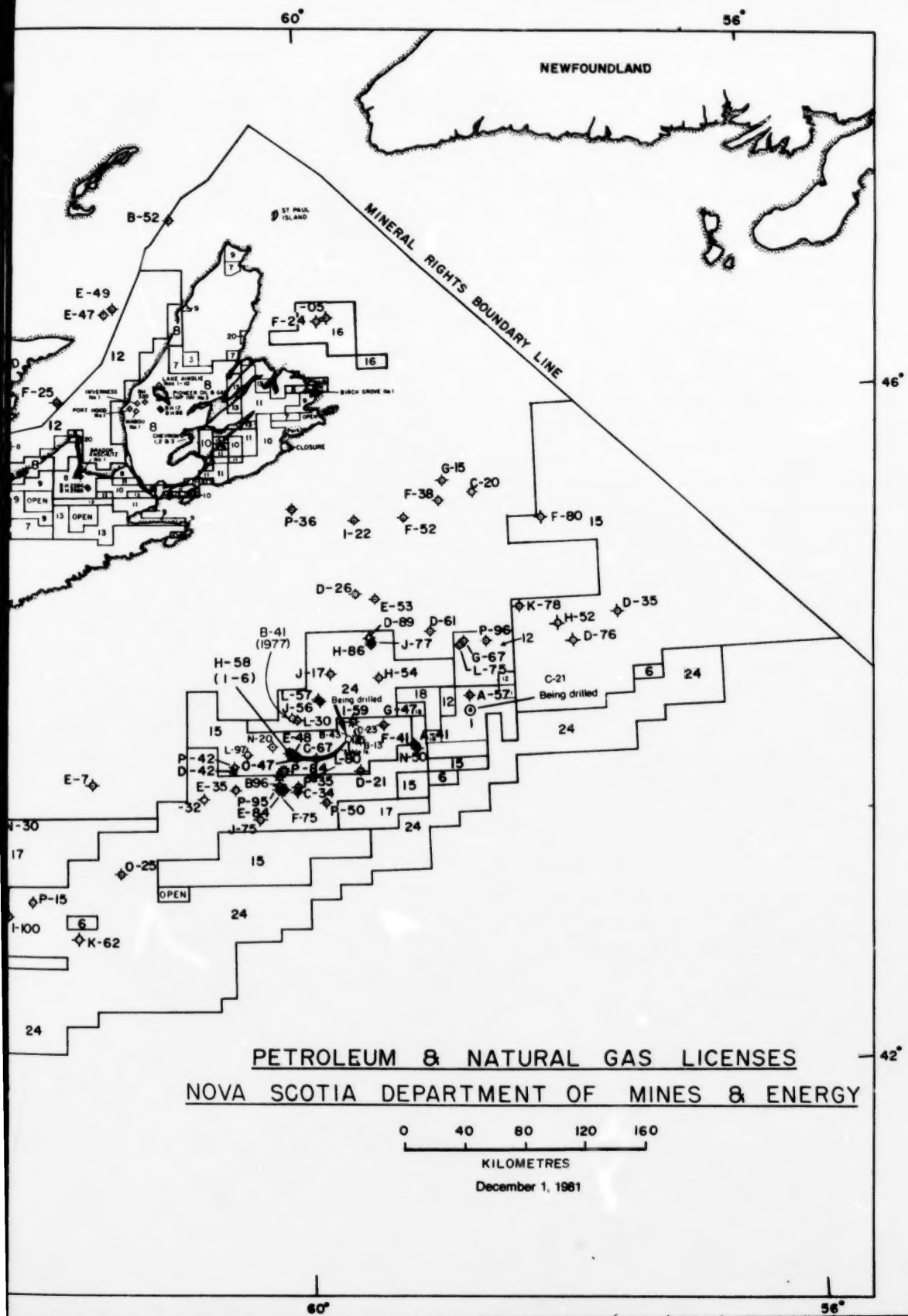


Figure 1. Petroleum and Natural Gas Licenses.




60°
56°
NEWFOUNDLAND
MINERAL RIGHTS BOUNDARY LINE
ST PAUL ISLAND
B-52
E-49
E-47
F-25
F-24
-05
16
12
8
20
17
7
3
9
OPEN
13
10
11
CLOSURE
BIRCH GROVE No.1
G-15
C-20
F-38
P-36
I-22
F-52
F-80
15
46°
D-26
E-53
D-89
D-61
K-78
H-52
D-35
P-96
D-76
B-41
(1977)
H-86
J-77
G-67
L-75
H-58
(1-6)
J-17
H-54
C-21
Being drilled
A-57
L-57
Being drilled
J-56
I-59
G-47
L-30
18
6
24
N-20
E-48
C-67
F-41
N-30
P-42
D-42
L-97
O-47
P-64
L-80
E-7
E-35
B96
P-95
E-84
C-34
D-21
P-35
F-75
P-50
-32
N-30
17
J-75
O-25
P-15
I-100
K-62
42°
PETROLEUM & NATURAL GAS LICENSES
NOVA SCOTIA DEPARTMENT OF MINES & ENERGY
0 40 80 120 160
KILOMETRES
December 1, 1981
60°
56°

1 · Origin and Accumulation

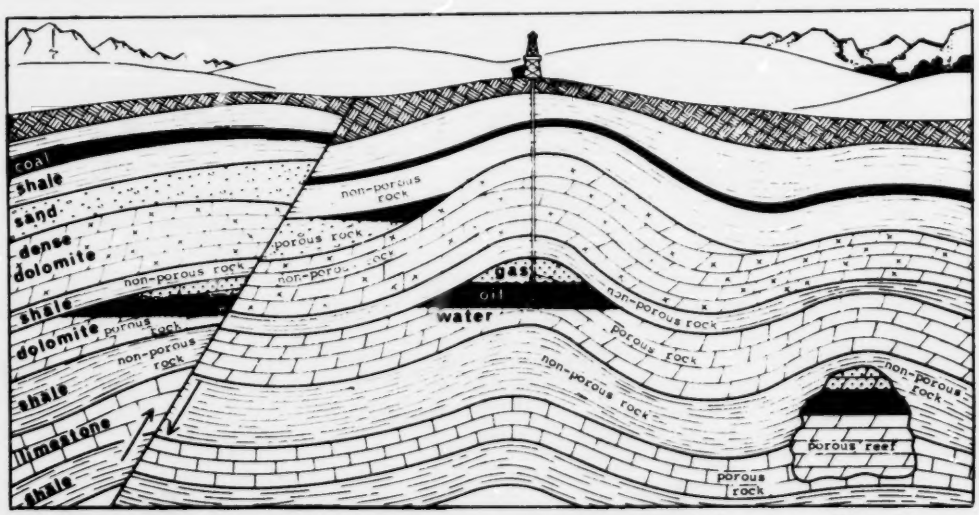
Petroleum (from Greek meaning — "rock oil") is a general term used to include all generated and commercially produced hydrocarbons from natural gas (methane) to crude oils and solid (asphaltic or paraffin) residues. This encompasses a tremendous range of molecular structures with a large range of physical properties combined with numerous impurities.

Petroleum is always found in, or associated with, sedimentary source rocks which, as newly deposited sediments, contained an abundance of plant or animal remains (organic material). The actual processes that took place to change organic remains into complex and varied hydrocarbons are only partly known because the time element — thousands of years — is not reproducible in laboratories. Evidence indicates that plant life is probably predominant as a basic contributor over animal life.

Since Cambrian time (600 million years ago), life forms have proliferated with the result that commercial petroleum is found in sedimentary rocks of all ages, in generally increasing quantities, up to recent times. Petroleum accumulated in various areas of the world during different ages as a result of the environmental conditions. In many areas accumulations from different ages are superimposed in rocks that vary in age by more than 200 million years. Even "new" rocks of the Quaternary Period (the last one million years) contain petroleum oils and gases, but only in a few cases have these had time to migrate into suitable reservoirs from which they can be recovered commercially.

To be recoverable, hydrocarbons must leave their disseminate and miniscule state in the fine grained source rocks and move into porous sandstones, limestones or fractured rocks (reservoirs), where they are concentrated and can be withdrawn through drilled holes. Contrary to popular belief, oil does not exist underground in pools or lakes, but is found in the pore spaces of rock. The mechanism of movement or migration of the hydrocarbons to the pore spaces is largely unknown. What is known is that this movement is aided by the presence of water (usually salt water) in the sediments, and by compaction (squeezing), a result of burial under additional sediments.

This is illustrated by the accumulation of billions of cubic metres of oil and gas in relatively small volumes of reservoir rock which contain our present giant fields.



FAULT TRAP — the strata have slipped so that a porous layer of rock is shoved against a non-porous layer.

STRATIGRAPHIC TRAP — caused by a "pinching out" of a porous rock layer between non-porous rock layers.

ANTICLINE — an upward arching of the rock strata. Oil and gas can collect in the porous rock, beneath the "inverted bowl" of non-porous rock.

REEF — a porous mound or mass built by animals such as corals.

Figure 12.
Geological Traps for Hydrocarbons.

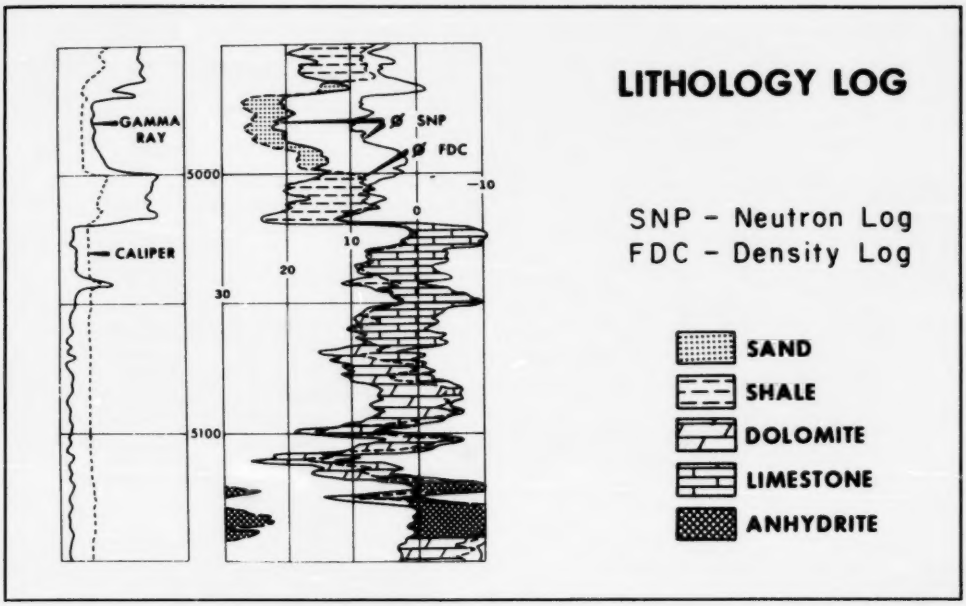


Figure 13. Lithology Log.

The movement of hydrocarbons into a porous reservoir is only the first step, however. The migration will continue in the porous formation until it escapes to the surface (as at the Athabasca tar sands in Alberta) or is retained below by some subsurface barrier called a trap. The shapes and styles of traps are many but are usually related to the geological history of any particular area (Figure 12). The common element in all traps is that further migration or flushing (by water) of the hydrocarbons toward the surface is prevented by overlying impermeable formations — as an inverted dish will retain air when immersed in water.

A further requirement of the trap is that it be preserved. Trapped oil and gas can be lost by faulting, as at the Santa Barbara Channel where seepage to the seafloor is slow but continuous. It is very possible that more oil and gas have been "lost" during geological time than have been preserved in traps so far discovered.

In the natural state, oil and gas always exist at a pressure greater than atmospheric, a condition which, when tapped, forces the liquid and gases to flow upwards. This is called a "primary recovery". The rate at which oil will move through the rock towards the well bore will depend on the reservoir pressure, the pressure at the bottom of the well, the permeability of the rock and the viscosity of the oil. As the oil is removed from the rock, the pressure of the reservoir will decrease and consequently the rate of production will tend to decline unless the pressure is sustained. The producer must then turn to artificial methods to restore reservoir pressure. This is called "secondary" or enhanced recovery and is accomplished by injecting water, natural gas or chemicals into the reservoir to force the petroleum through the rock and up the well bore.

2 · Exploration Procedures

How it is Found

Oil and gas are relatively inert with no particular qualities that allow any specific measurement from a distance. The geologist and geophysicist use both "direct" and "indirect" methods to discern the geological structures in the subsurface which could comprise a trap for accumulation. Geological methods include a study of the surface rocks, or seafloor beds where exposed, and/or a study of subsurface rocks

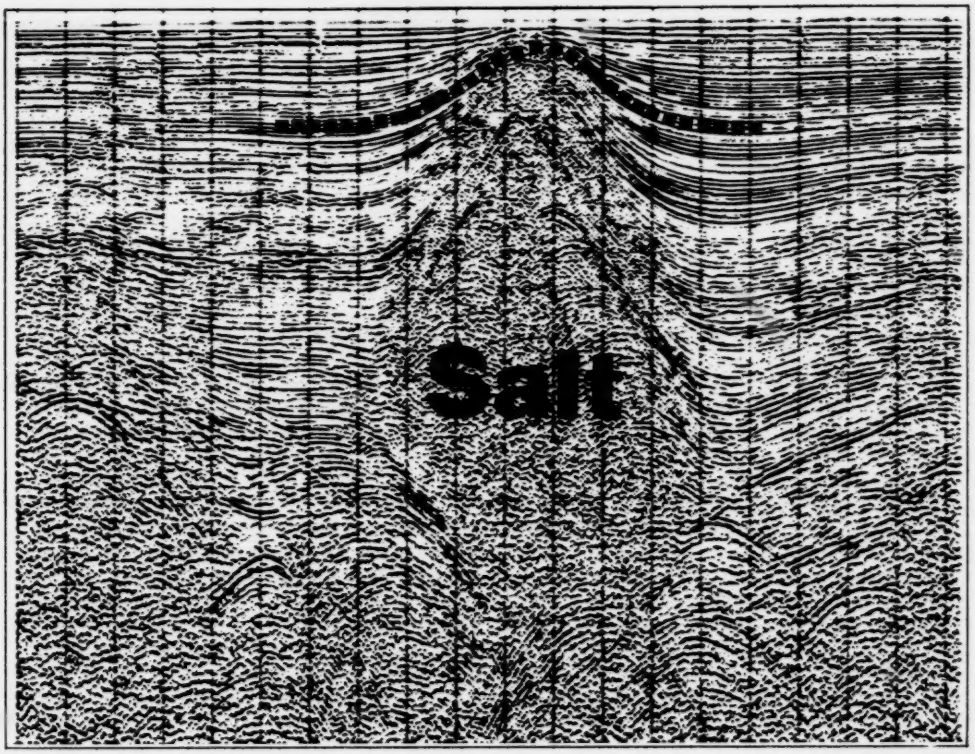


Figure 14. Seismic profile showing salt piercement structure.

from previously drilled holes using samples and downhole logs. Downhole logs have several uses and are in fact, one of the most important tools of exploration geology. By lowering electrodes into the hole on an insulated cable, the electrical resistance and other mechanical properties of the penetrated formations can be measured and recorded at the surface (Figure 13). An idea of porosity and lithology may be interpreted from the logs. For example, sandstone saturated with salt water has a low resistance, while sandstone filled with oil and gas has a high resistance. Oil and gas can be indicated using a combination of logs and a precise depth determined. The logs are also of great use in correlating and evaluating formations between wells to help determine some interpretation of the potential of that area.

Geophysical methods include measurements of magnetic or gravity forces, radiometric or electrical characteristics, or acoustic (sound) wave propagation, called seismic. Seismic is the predominant geophysical method and has been in use for more than fifty years. For the offshore, it is the primary forerunner to pinpoint drilling locations. Basically it is a simple principle. An acoustic wave is initiated at the surface and the elapsed time of echoes from the various reflecting rock strata at depth are recorded. The longer the time from impulse to return of reflection, the deeper the particular bed lies below the surface. Thus a tilted (dipping) bed will give an increased time of reflection as the recorder moves from where a bed is shallow to where it is deeper. Intermittent recordings obtained along a line are processed into a continuous profile which gives a graphic portrayal of those beds that generate reflections of the acoustic wave (Figure 14). In one method of creating seismic waves, a vibrator truck creates shock waves that penetrate the earth's crust (Figures 15(a) and (b)).

In a general sense, the profile shows the rock layers and their deformation by folding, faulting or piercement by salt or shale intrusions. By using a grid, or network, of such profiles and by following a specific reflection, a contour map of subsurface strucure is constructed — much as a topographic map of the earth's is made. (The topographic hills and ridges of the surface map are similar to domes and anticlines in the subsurface while the valleys between are similar to the synclines. A sharp cliff or locally steep slope is akin to a fault).

Such a map, or maps, indicate structural domes, anticlines, faults, and other features which could form traps for hydrocarbons. The actual depths at which these maps are made may vary from 100 m to more than 6000 m below the surface, depending on the thickness and the acoustical "transparency" of the column of sedimentary rocks and the estimated depth to potential oil or gas bearing formations.

It is, of course, necessary to know the surface positions from which all the recordings are made so the locations of possible drill sites can be relocated with accuracy. This is done on the recording boat by radio positioning from known stations on shore or by using the earth satellites as they traverse overhead.

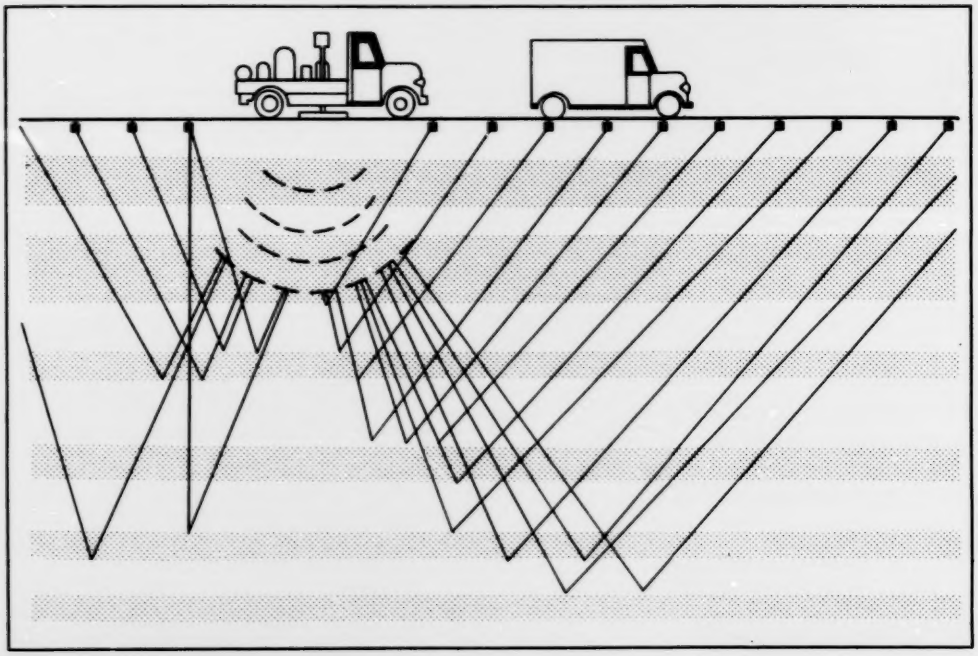


Figure 15(a) Schematic representation of shock waves created by vibratbr truck, reflected on lithology and recorded, creating the seismic profile (Figure 14).

Figure 15(b). Vibrator truck as used recently throughout the province.

3 · Drilling and Development

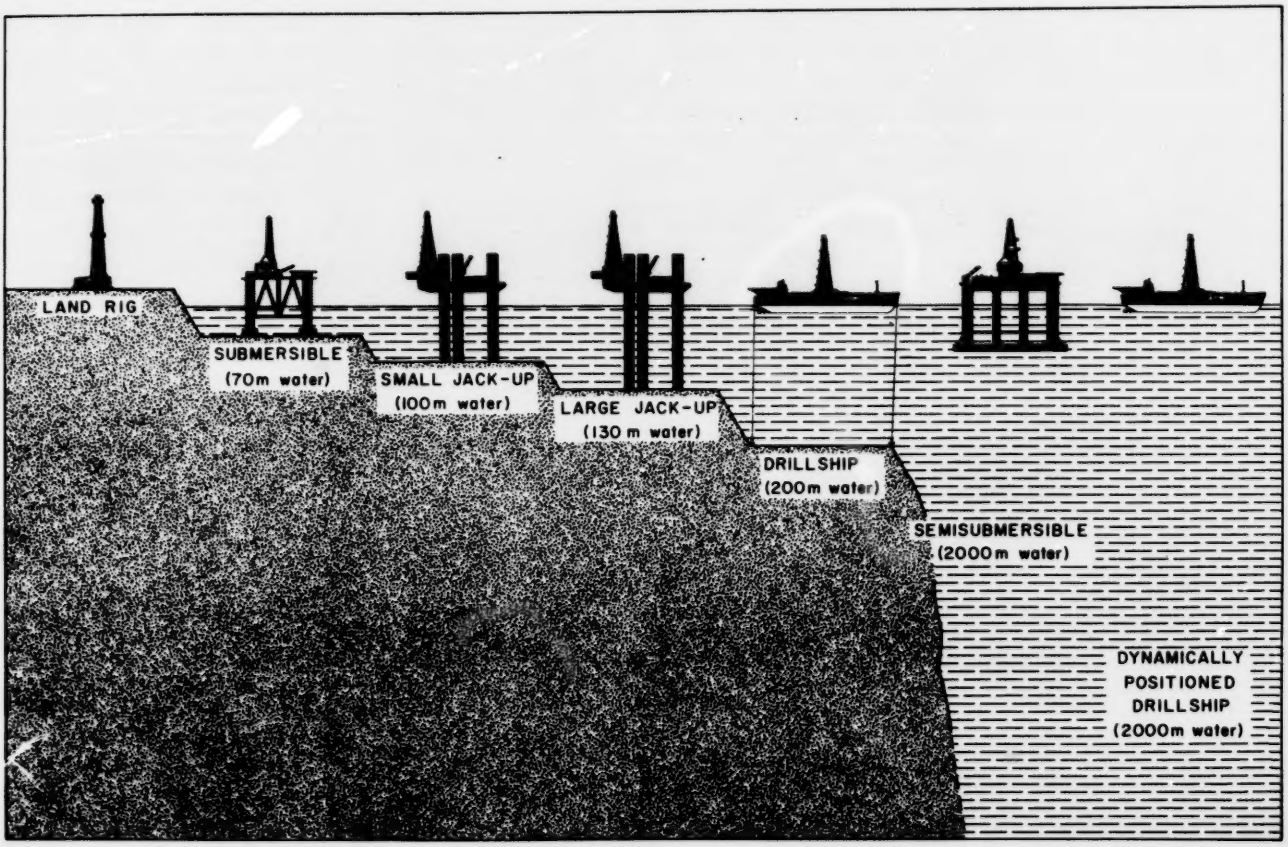
Once a drilling location is determined by geologists, geophysicists and management, a drilling contractor is found who has the suitable equipment for the particular water conditions and proposed depth of the hole (Figure 16).

If the well is located in relatively shallow water, a jack-up drilling rig may be used (Figure 17). This vessel is floated to the site, and its legs lowered so that it sits on the seafloor and only its drilling deck and equipment are above the waves. Because it actually sits on the sea floor, the depth in which it can be used is limited.

In deeper waters, the drilling contractor must turn to drill ships or semi-submersible drilling barges. Drill ships are exactly that, ships which house a drilling rig on their deck. The ship reaches the site, is anchored in position and carries out its drilling duties through its hull. A semi-submersible drilling barge displaces as much as 50 000 tonnes of water and may equal a battleship in weight. To operate, it is moved into position, and held in place by anchors or by computer controlled thrusters. Then the hull is submerged so that part of the vessel sinks below the surface with the drilling deck remaining above water. Since only a few columns emerge above the water line, impact of hostile winds and waves is minimized.

Once the drilling vessel is in position operations can begin. After a conductor pipe, 66 cm to 76 cm in diameter, is driven 30 m to 100 m into the seafloor and cemented drilling begins. The drill bit cuts a hole about 55 cm in diameter and between 300-600 m deep, a pipe is lowered into it and cement is forced between it and the wall of the hole. This is called casing. A blowout preventer stack is installed to contain accumulations of gas or oil that may be encountered in further drilling. More casing of smaller diameter may be cemented into place as the hole is deepened.

Figure 16. Offshore Mobile drilling units.



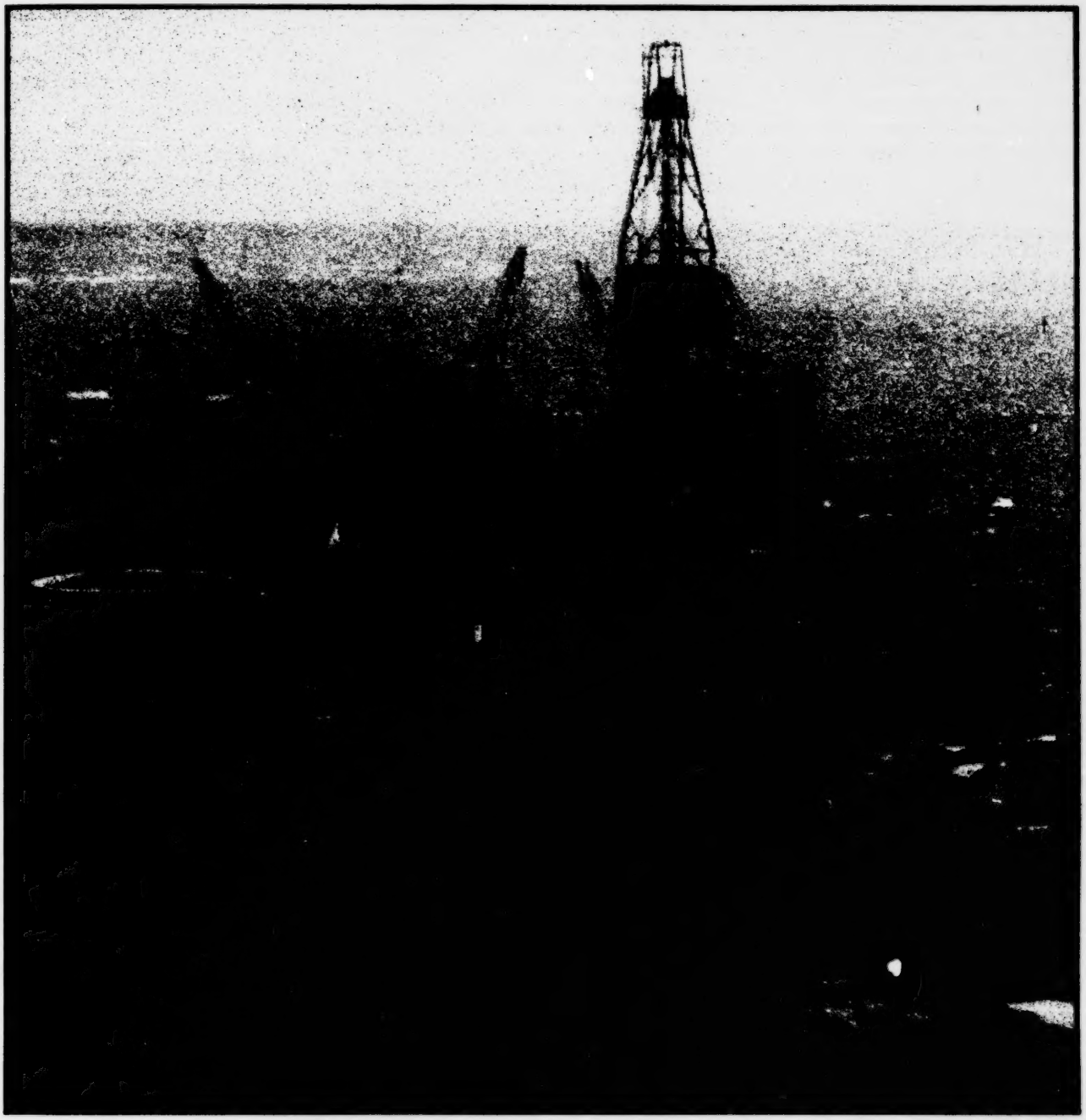


Figure 17. Rowan Juneau Jack-up Rig. Presently drilling for Mobil near Sable Island.

Now, drilling mud becomes of utmost importance. This special mixture of clay, water and chemical additives circulates through the drill pipe and cools and lubricates the rotating bit. The mud flows through the drill bit to wash cuttings back to the surface (providing information about the various formations being cut), to cool the bit as it rotates, and to hold the pressure against the various formations. The presence of oil and gas can sometimes be detected by analyzing the returning mud at the surface.

During the drilling operation, core samples may be taken to obtain information on the exact nature of the stratigraphy which has been penetrated. This is done in one of two ways. As the hole is being drilled, a special bit may be attached

to the drill pipe and lowered into the hole and a core cut and collected in a cylinder. Secondly, projectiles may be fired into the wall of the hole at certain depths penetrating the formation and collecting a small core. The latter method can be used after drilling is completed and downhole log surveys have been made. In those zones where favourable conditions are indicated by the logs, drill stem tests may be conducted. These tests allow fluids to ascend to the surface from the zones so samples can be taken and the pressure and flow rates monitored.

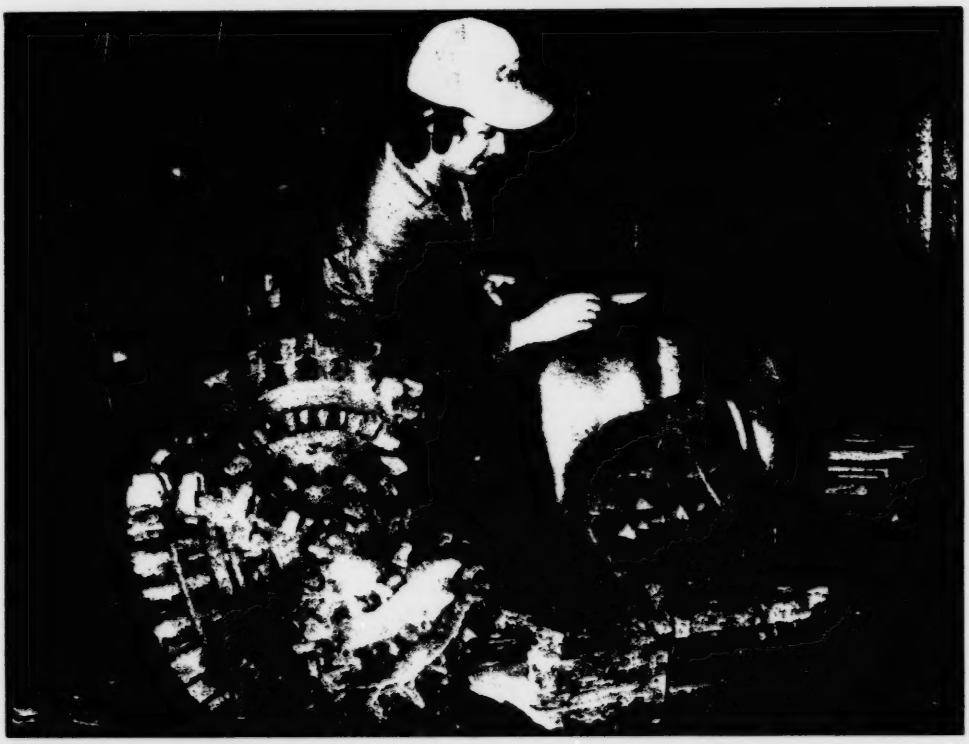
If it is determined that the reserves of this discovery well are sufficient to provide enough money to pay for further development plus yield a profit, engineering tests will begin.

Production casing will later be inserted into the hole. This will prevent the hole from caving in, control the flow of fluids between formations, confine the production to the specific area indicated to contain hydrocarbons, and permit the installation of equipment necessary for production.

The drilling contractor will then drill a series of confirmation or step-out holes to delineate the field. With the data from the drill stem tests, downhole logs and samples combined with the geological and geophysical maps, the determination of the extent of the producing area, the calculation of the volume of oil and gas, an estimate of producible reserves can finally be made.

Studies are then made to determine the number of producing wells to be drilled, their spacing, the number and locations of producing platforms to be installed, and how the product is to be stored and transported to shore.

It should be pointed out that exploratory drilling will continue even after the development of a field has begun, and will be carried on for many years simultaneously with development work (Table II).



Large 660mm Drill Bits used to drill the top section of an offshore oil and gas well.

A Relative Time Frame For Offshore Production of Hydrocarbons

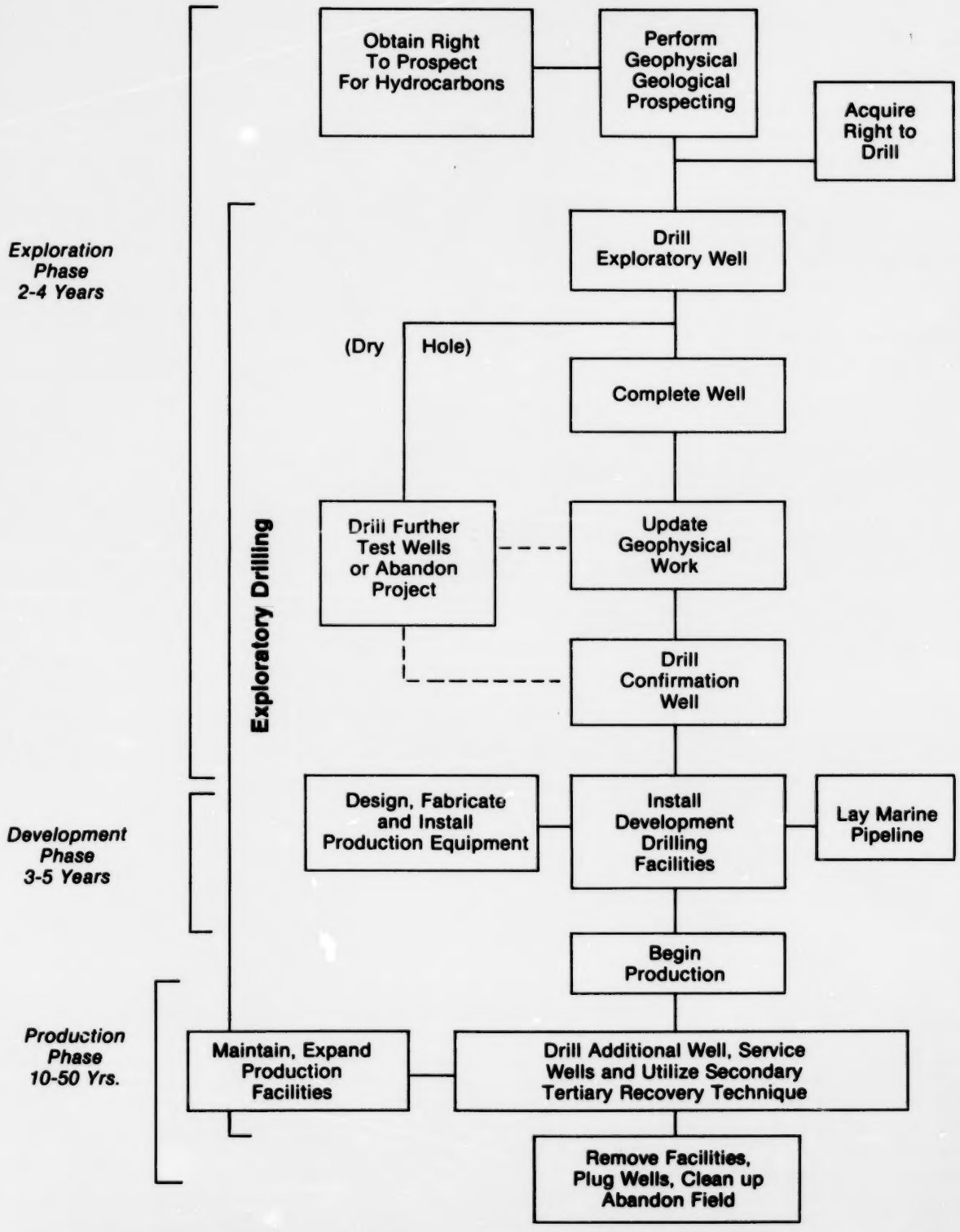

Obtain Right To Prospect For Hydrocarbons
Perform Geophysical Geological Prospecting
Acquire Right to Drill
Exploration Phase 2-4 Years
Drill Exploratory Well
(Dry Hole)
Complete Well
Exploratory Drilling
Drill Further Test Wells or Abandon Project
Update Geophysical Work
Drill Confirmation Well
Design, Fabricate and Install Production Equipment
Install Development Drilling Facilities
Lay Marine Pipeline
Development Phase 3-5 Years
Begin Production
Production Phase 10-50 Yrs.
Maintain, Expand Production Facilities
Drill Additional Well, Service Wells and Utilize Secondary Tertiary Recovery Technique
Remove Facilities, Plug Wells, Clean up Abandon Field

Table II.

4 · Production

Once the precise nature of the field is determined including factors such as: oil or gas; location; weather conditions of the area; the function to be performed; and if a drilling platform is used, then the number of wells to be drilled from the offshore structure can be determined. Engineering work begins, utilizing civil, mechanical, electrical, chemical and instrumental engineers for the various aspects of the project. Marine engineers calculate data necessary to launch and set the structure in place once fabricated and draftsmen carefully translate these calculations into a technical picture.

By using directional drilling techniques one platform can produce as many as 50 wells. The platform consists of a jacket pinned to the ocean floor by piling. A deck station is placed on piles braced by the jacket. On this deck may be whatever is required at the location.

Because offshore structures must first withstand the horizontal forces of winds up to hurricane velocity, and waves as high as 30 m or more, probing research must be done into the environmental requirements of the structure. When the configurations of steel are computed for the requirements of man and regulatory agencies, final drawings can be prepared for use by the fabricating yards and material can be ordered.

The engineers determine the most practical and economical way to achieve the customer's needs. It is a time consuming process. The procedure might be simplified, if not hastened, if each structure was like the one before with only minor changes in requirements needed. Such is not the case, however, for each structure is unique. Each set of variables must be studied and resolved before one step in the design phase can be completed and the next begun.

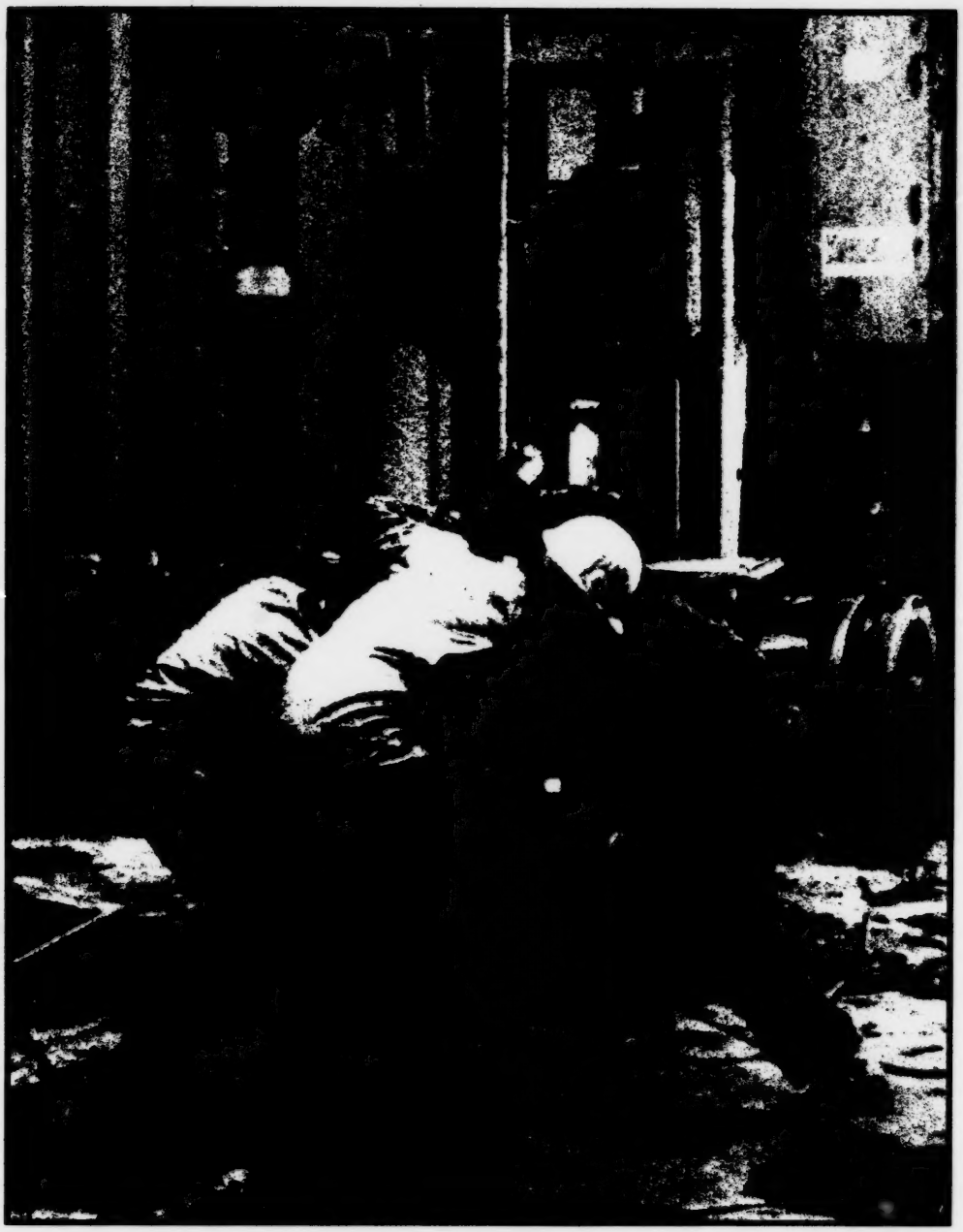
After the drawings have been sent to the fabrication yard, actual work on the structure begins. The time needed in the actual fabrication of a structure varies from 4 to 12 months depending on its size and complexity.

The components of each structure are fabricated into the largest possible units that may be economically and expeditiously transported from the fabrication yard to the job site. This minimizes the time at sea that erection operations are exposed to weather delays which would result in increased costs.

Once the jacket is completed and its accompanying deck sections ready, it is transported by barge to the installation site where giant derrick barges lift and position the man-made real estate. The giant bases or templates of the structure sit on the seafloor. It is these templates with piles driven through the legs that absorb the forces of perpetual movement of the waters, while supporting the deck sections and equipment above the ocean's reach.

The difference in the functions of the various platform structures may not be apparent to the layman's eye, but there are important differences in each.

The tender-type platform may appear to be nothing more than and offshore drilling structure with a barge moored alongside. This barge is, in reality, a drilling tender and is critical to the total performance of the complex. For economic reasons, the drilling structure has been designed to support only a minimum of the equipment required. All support requirements such as living areas, storage facilities, drilling mud, and large mechanical components of the system are aboard the attending vessel. This vessel "tends" to the operating functions of the drilling rig on the platform. Because these components do not have to be on the structure, the required deck space is less, making fabrication time somewhat shorter reducing installation and set up time. This kind of structure is not generally used in deeper waters where more extreme conditions make holding the tender alongside more difficult.



Roughnecks at work.

On the other hand, the larger self-contained platform attends itself in even the most hostile environments. All components necessary for day to day operations are contained on the structure. It is a unit independent of the need of assistance for its continual operation, and is supplied by supply boats, crew boats, and helicopters in good weather and calm sea conditions.

When a platform is used for drilling only, the well stream must be transported via pipeline to another facility for processing. This is when the production platform must be used. This self-contained unit will take the well stream from the reservoir, separate the oil, natural gas, water and other materials, and ready them for the trip to shore by steel pipelines lying on or buried in the ocean floor. The size of the platform and the required equipment, such as gas compressors, crude oil pumps, or gas and oil separators is determined by the quantity and composition of the well stream.

Today, with advanced design technology, we have placed into service around the world, massive combination drilling and production platforms on which the drilling and production sequences take place simultaneously. Using this method of operation, companies save money and valuable time in this production process.

While the production platforms are being installed, pipelaying barges are busy preparing the means of transporting the oil and gas ashore to other platforms or to loading and unloading facilities. Barges as long as 150 m supplied by material barges from onshore bases, lay kilometre after kilometre of weight-coated (concrete-coated) pipe onto the seafloor. The pipe, ranging in size up to 1400 mm is usually in 12 m sections called joints. These joints are welded together by passing through as many as seven welding stations on the pipelaying barge and are then x-rayed to insure flaw free connection and finally, the newly walled area is coated for corrosion protection. It then goes off one end of the barge guided by a support system called a stinger. This device insures a correct curve while the pipe is descending and thus keeps the pipe from excessive bending and possible buckling.

During the laying process divers descend into the waters to inspect the pipe and seafloor. They make certain that no obstructions have come between the pipe and seafloor, and that the stinger is providing the necessary support to gently lower the pipe at the proper angle to the bottom. When the line reaches the platform the divers will again descend for the riser installation. A riser is an extension to the piping system from an offshore production platform. It connects the production facilities with the subsea line.

The pipeline does not rest on the seafloor which would be vulnerable to disruption. A small jet barge, will create a trench in which the pipe will rest by passing over the pipe with a specially designed sled which has high pressure hoses that force air and water beneath the pipe to create a trench into which the pipe settles. The natural movement of the currents on the seafloor surface will cover the line in the trench thus protecting the line from possible damage.

The destination of the pipelines may vary. They may terminate at an offshore gathering station where the oil and gas is further separated and transmitted through other lines to other points. They may terminate onshore where huge tank farms store the liquid hydrocarbons for distribution to refineries throughout the world.

Distribution can be accomplished in various ways depending on the market, the availability of onshore processing facilities and the location of the particular operating company's facilities. From the tank farms, kilometres of underground pipelines may carry the oil and natural gas to processing plants. Pipelines reaching from the tank farms back to the water will allow crude carriers (tankers) to load and unload the oil for distribution to or from other global markets.

From huge onshore gas and crude oil processing plants designed and built by the oil, gas and chemical companies, the vital crude and natural gas are then readied for final application. From these plants the materials needed for gasoline, motor oil, synthetic fabrics, plastics, asphalt and the innumerable end products we derive from oil will be distributed.

Finally, after the long exploration, development and production process (see Table II), the natural gas will find its way (from processing plants) to the consuming areas of the world to provide clean energy to light our homes, cook our foods, dry our clothes, and become the feed-stock of a myriad of petrochemical industries.

*** NOTE: This article discusses one production system only. There is no guarantee that this type of system will be used in the province.

Appendix

Data on recent and current wells is subject to minor change.

ABBREVIATIONS

RT - Rotary Table
KB - Kelly Bushing
GL - Ground Level
P & A - Plugged and Abandoned
P & S - Plugged and Suspended
TD - Total Depth

WELL SYMBOLS

- Drilling
- Plugged and Abandoned
- Significant Gas
- Gas Show
- Significant Oil
- Oil Show
- Significant Oil and Gas
- Plugged and Suspended
- Significant Oil, Suspended
- Oil and Gas Show

Exploratory Wells Drilled in the Nova Scotian Offshore

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status
Mobil Sable Island C-67	43° 56′ 04.9″ 59° 55′ 01.4″	Bawden Rig 18	67-06-07 68-01-02	8.2 KB 3.9 GL	4 604.3 P & A
Shell Onondaga E-84	43° 43′ 16.14″ 60° 13′ 17.41″	Sedneth 1	69-09-01 69-11-11	25.9 57.9	3 988.3 P & A
Shell Oneida O-25	43° 14′ 57.36″ 61° 33′ 36.49″	Sedneth 1	69-11-16 70-02-10	25.9 82.3	4 119.9 P & A
Shell Naskapi N-30	43° 29′ 46.78″ 62° 33′ 59.54″	Sedneth 1	70-02-16 70-03-19	26 95.1	2 205.2 P & A
Shell Mohawk B-93	42° 42′ 10.52″ 64° 43′ 53.50″	Sedco H	70-05-03 70-05-23	31.4 117	2 126 P & A
Shell Mic Mac J-77	44° 36′ 42.81″ 59° 26′ 10.86″	Sedneth 1	70-03-25 70-05-24	26 62.8	3 886.2 P & A
Shell Abenaki L-57	44° 16′ 34.49″ 59° 53′ 39.64″	Sedco H	70-05-28 70-07-06	31.4 108.8	2 178.4 P & A
Shell Missisauga H-54	44° 23′ 20.39″ 59° 22′ 47.56″	Sedneth 1	70-05-26 70-07-20	25.9 102.1	4 202.3 P & A
Shell Onondaga O-95	43° 44′ 48.09″ 60° 13′ 52.60″	Sedco H	70-07-09 70-08-16	31.4 53.9	3 314.4 P & A
Shell Huron P-96	44° 35′ 47.10″ 58° 28′ 50.63″	Sedneth 1	70-07-22 70-08-27	25.9 57.9	3 018.4 P & A
Shell Iroquois J-17	44° 26′ 31.37″ 59° 47′ 12.28″	Sedco H	70-08-18 70-09-06	31.4 59.4	2 086.4 P & A
Shell Cree E-35	43° 44′ 20.70″ 60° 35′ 55.89″	Sedco H	70-09-08 70-11-03	31.4 53.3	3 983.7 P & A
Shell Mic Mac H-86	44° 35′ 27.71″ 59° 27′ 03.12″	Sedneth 1	70-08-31 70-12-02	25.9 54.3	4 785.4 P & A
Shell Wyandot E-53	44° 52′ 20.70″ 59° 23′ 54.05″	Sedco H	70-11-07 70-12-14	31.4 121	3 049.5 P & A
Shell Argo F-38	45° 27′ 23.22″ 58° 50′ 24.34″	Sedco H	70-12-17 71-02-19	31.4 71.6	3 386.3 P & A
Shell Fox I-22	45° 21′ 33.60″ 59° 33′ 16.00″	Sedco H	71-02-20 71-03-03	31.4 83.8	829.7 P & A
Shell Abenaki J-56	44° 15′ 44.95″ 59° 53′ 03.02″	Sedneth 1	70-12-04 71-03-13	25.9 106.7	4 569.3 P & A
Shell Erie D-26	44° 55′ 03.52″ 59° 34′ 29.82″	Sedneth 1	71-03-16 71-04-11	25.9 98.1	2 375.9 P & A
Mobil-Tetco Esperanto K-78	44° 47′ 31.26″ 58° 11′ 19.24″	Sedco H	71-03-09 71-04-24	31.4 68.6	3 540.3 P & A
Shell Crow F-52	45° 21′ 24.23″ 59° 08′ 22.73″	Sedneth 1	71-04-12 71-04-27	25.9 94.5	1 506.6 P & A
Shell Sauk A-57	44° 16′ 05.70″ 58° 37′ 44.41″	Sedneth 1	71-04-30 71-07-10	25.9 60	4 575 P & A

Offshore cont'd

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status	
Mobil-Tetco Dauntless D-35	44° 44′ 08.26″ 57° 20′ 46.62″	Sedco H	71-04-26 71-07-16	31.4 69.2	4 741.2 P & A	✧
Shell Chippewa L-75	44° 34′ 35.87″ 58° 41′ 50.54″	Sedneth 1	71-07-12 71-08-02	24.7 67.7	2 125.9 P & A	✧
Shell Onondaga F-75	43° 44′ 17.84″ 60° 11′ 36.25″	Sedco H	71-07-28 71-09-07	31.4 56.4	3 890.8 P & A	✧
Shell Triumph P-50	43° 39′ 51.62″ 59° 51′ 02.36″	Sedneth 1	71-08-04 71-10-10	25.9 90.2	4 595.4 P & A	✧
Mobil-Tetco Sable Island E-48	43° 57′ 20.35″ 60° 07′ 24.44″	Bawden Rig 14	71-05-28 71-10-15	6.4 0	3 602.7 P & S	✸
Shell Eurydice P-36	45° 25′ 47.30″ 60° 04′ 46.97″	Sedco H	71-09-15 71-10-24	29.9 164.6	2 965.1 P & A	✧
Shell Chippewa G-67	44° 36′ 20.50″ 58° 39′ 44.62″	Sedco H	71-10-28 71-12-18	29.9 70.1	3 669.8 P & A	✧
Shell Mohican I-100	42° 59′ 39.04″ 62° 28′ 51.12″	Sedco H	71-12-27 72-03-10	29.9 153.3	4 393.4 P & A	✧
Shell Marmora C-34	43° 43′ 13.79″ 60° 05′ 21.93″	Sedneth 1	72-01-15 72-03-31	25.9 57.6	4 037.9 P & A	✧
Shell Primrose N-50	43° 59′ 48.43″ 59° 06′ 51.63″	Sedco H	72-03-14 72-04-21	29.9 90.8	1 713.6 P & A	✸
Mobil-Tetco Sable Island O-47	43° 56′ 56.70″ 60° 06′ 38.08″	Bawden Rig 14	71-12-13 72-07-01	7 KB 1.8 GL	4 198.6 P & S	✲
Shell-Mobil- Tetco Eagle D-21	43° 50′ 06.73″ 59° 34′ 09.21″	Sedco H	72-04-22 72-07-02	29.9 51.2	4 660.4 P & A	✧
Mobil-Tetco Sable Island 1-H-58	43° 57′ 27″ 60° 07′ 37″	Bawden Rig 9	72-06-03 72-08-27	10.7 KB 1.8 GL	3 039.2 P & S	✸
Mobil-Tetco- Thebaud P-84	43° 53′ 59.53″ 60° 12′ 19.34″	Sedco H	72-07-08 72-10-13	28.6 25.9	4 114.8 P & S	✲
Mobil-Tetco Sable Island 2-H-58	43° 57′ 27.14″ 60° 07′ 37.75″	Bawden Rig 9	72-10-06 72-12-31	10.6 KB 1.8 GL	2 758.4 P & S	✸
Shell Primrose A-41	44° 00′ 05.68″ 59° 06′ 18.26″	Sedco H	72-10-15 73-01-27	29.9 109.7	3 616.5 P & A	✧
Shell Primrose F-41	44° 00′ 29.55″ 59° 07′ 06.52″	Sedco H	73-01-30 73-03-05	29.9 68.6	2 592.3 P & A	✧
Mobil-Tetco Sable Island 3-H-58	43° 57′ 27.2″ 60° 07′ 37.8″	Bawden Rig 9	73-01-01 73-03-21	10.6 KB 1.8 GL	3 739.9 P & S	✲
Shell Marmora P-35	43° 44′ 59.36″ 60° 04′ 47.58″	Sedco H	73-03-06 73-04-21	29.9 53.3	4 092.9 P & A	✧
Mobil-Tetco Bluenose G-47	44° 06′ 20.79″ 59° 21′ 27.35″	Sedco J	73-01-25 73-04-25	29.9 81.4	4 587.2 P & A	✧
Shell Tuscarora D-61	44° 40′ 10.35″ 58° 55′ 10.85″	Sedco H	73-04-23 73-06-02	29.9 78.9	3 939.5 P & A	✧

Offshore cont'd

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status
Mobil-Tetco Cohasset D-42	43° 51′ 06.52″ 60° 37′ 13.89″	Sedco J	73-04-27 73-07-16	31.4 41.1	4 427.2 P & S
Mobil-Tetco Sable Island 4-H-58	43° 57′ 27.2″ 60° 07′ 37.8″	Bawden Rig 9	73-03-22 73-08-11	10.6 KB 1.8 GL	4 519.3 P & S
Mobil-Tetco Sable Island 5-H-58	43° 57′ 27.2″ 60° 07′ 37.8″	Bawden Rig 9	73-08-15 73-09-18	10.6 KB 1.8 GL	2 478 P & S
Mobil-Tetco Sable Island 6-H-58	43° 57′ 27.2″ 60° 07′ 37.8″	Bawden Rig 9	73-09-22 73-10-18	10.6 KB 1.8 GL	2 355.2 P & A
Union et al Shell Ojibwa E-07	43° 46′ 20.44″ 61° 46′ 14.42″	Sedco H	74-02-04 74-02-28	29.9 75.6	2 329.6 P & A
Mobil-Tetco-Texaco Citnalta I-59	44° 08′ 42.58″ 59° 37′ 32.11″	Sedco J	74-02-04 74-04-29	29.9 94.5	4 575 P & S
Shell Demascota G-32	43° 41′ 27.2″ 60° 49′ 54.00″	Sedco H	74-03-01 74-05-20	29.9 54.3	4 672.3 P & A
Union et al Sambro I-29	43° 38′ 35.04″ 62° 48′ 17.04″	Sedco H	74-05-23 74-06-27	29.9 193.5	3 069.6 P & A
Union et al Jason C-20	45° 29′ 05.45″ 58° 32′ 28.27″	Sedco H	74-07-03 74-07-22	29.9 112.8	2 482.9 P & A
Union et al Hercules G-15	45° 34′ 20.65″ 58° 47′ 13.06″	Sedco H	74-07-23 74-08-01	29.9 115.8	1 081.1 P & A
Texaco-Shell Intrepid L-80	43° 49′ 35.78″ 59° 56′ 43.82″	Sedco J	74-05-18 74-08-15	31.4 43.6	4 162 P & A
Murphy et al North Sydney P-05	46° 34′ 46.24″ 59° 45′ 01.65″	Sedco H	74-08-10 74-09-07	29.9 62.8	1 660.9 P & A
Union et al Montagnais I-94	42° 53′ 40.71″ 64° 13′ 46.51″	Sedco H	74-09-12 74-09-29	29.9 112.8	1 645.9 P & A
Mobil-Tetco-Gulf Adventure F-80	45° 19′ 27.54″ 57° 56′ 22.80″	Sedco J	75-01-13 75-02-22	29.9 98.8	1 999.2 P & A
Mobil Texaco Sachem D-76	44° 35′ 09.22″ 57° 41′ 58.29″	Sedco J	75-05-17 75-07-30	29.9 58.5	4 878.6 P & A
Shell Onondaga B-96	43° 45′ 08.23″ 60° 14′ 09.63″	Sedco H	76-01-12 76-03-21	29.9 60.4	3 757.6 P & A
Petro-Canada Shell Mic Mac D-89	44° 38′ 08.86″ 59° 28′ 18.93″	Sedco H	76-03-26 76-05-04	29.9 85.3	3 216.4 P & A
Petro-Canada Mobil Hesper I-52	44° 41′ 40.33″ 57° 52′ 32.24″	Sedco H	76-05-08 76-06-05	29.9 42.1	2 804.2 P & A
Shell et al North Sydney F-24	46° 33′ 23.13″ 59° 48′ 45.47″	Sedco H	76-06-09 76-06-14	29.9 59.7	1 706.8 P & A
Petro-Canada-Shell Penobscot L-30	44° 09′ 43.55″ 60° 04′ 09.33″	Sedco H	76-07-18 76-09-23	29.9 137.5	4 267.2 P & A
Petro-Canada-Shell Wenonah J-75	43° 34′ 34.43″ 60° 26′ 13.72″	Sedco H	76-09-26 76-11-15	29.9 66.7	3 669.8 P & A

Offshore cont'd

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status
Petro-Canada-Shell Moheida P-15	43° 04′ 56.31″ 62° 16′ 44.32″	Sedco H	76-11-18 77-02-15	29.9 111.9	4 297.7 P & A
Shell-Petro-Canada Penobscot B-41	44° 10′ 02.44″ 60° 06′ 34.50″	Sedco H	77-02-18 77-03-30	29.9 117.9	3 444.2 P & A
Mobil-Tetco-PEX Migrant N-20	43° 59′ 56.24″ 60° 17′ 18.23″	Gulftide	77-07-29 78-01-23	26.1 13.7	4 668.7 P & A
Mobil-Tetco PEX Thebaud I-94	43° 53′ 43.67″ 60° 13′ 38.13″	Gulftide	78-02-26 78-06-03	29.9 28	3 962.4 P & A
Chevron PEX Shell Acadia K-62	42° 51′ 42.54″ 61° 55′ 00.21″	Ben Ocean Lancer	78-04-11 78-08-02	12.8 866.2	5 286.1 P & A
Mobil-Tetco PEX Cohasset P-42	43° 51′ 48.23″ 60° 36′ 16.62″	Gulftide	78-06-09 78-07-10	30.5 34.1	2 590.8 P & A
Mobil-Tetco PEX C-Cohasset L-97	43° 56′ 37.19″ 60° 29′ 58.55″	Gulftide	78-07-13 78-11-13	30.5 21.6	4 871.9 P & A
Mobil Texaco PEX Venture D-23	44° 02′ 15″ 59° 34′ 21″	Gulftide	78-11-28 79-06-16	31.7 20.1	4 945 P & S
Mobil et al Venture B-13	44° 02′ 11.61″ 59° 32′ 03.54″	Rowan Juneau	80-08-17 81-06-06	33.8 24.7	5 212 P & S
Mobil et al Venture B-43	44° 01′ 45.01″ 59° 37′ 21.03″	Rowan Juneau	81-07-06	33.8 20.4	5 872 P & S
Petro-Canada et al Banquereau C-21	44° 10′ 08.00″ 58° 33′ 59.11″	Bowdrill I	81-12-02	27 83	Drilling
Mobil et al Olympia A-12	44° 01′ 03.27″ 59° 46′ 44.09″	Zapata Scotian	82-04-23	38.1 39.9	Drilling
Mobil et al South Venture O-59	43° 58′ 52.83″ 59° 38′ 08.49″	Rowan Juneau	82-04-29	35.4 24.4	Drilling

Exploratory Wells Drilled in the Nova Scotian Onshore

Well Name	Latitude Longitude	Drilling Unit	Spud Date Rig Released	RT Elev'n Water Depth	Depth (RT) Well Status
Imperial Malibu #1	11K/03	Imperial National #2	52-10-24 59-12-31	144.5m 139.3	1 658.2 P & A
Imperial Malibu #	11K/03	Imperial National #2	60-01-16 60-04-11	130.2m 125.0	2 999.2 P & A
Pacific Fox Harbour	45° 50′ 56.25″ N 64° 30′ 3687″ W	Commonwealth Rig #9	63-12-10 64-05-03	26.8m 23.0	3 003.29 P & A
Wallace No. 1	11E/14B	Petrolia Rig #5	66-07-04 66-08-27	75.6 72.0	1 222.6 P & A
Wallace No. 2	11E/14B	Petrolia Rig #5	66-09-03 66-09-27	51.5m 47.9	798.3 P & A
Murphy et al Birch Grove #1	46° 08′ 42.4″ N 59° 56′ 05.04″ W	Petrolia Rig #5	68-02-08 68-03-24	49.7 46.5	1 343.6 P & A
Anschutz Wallace Station #1	45° 46′ 15″ N 63° 30′ 30″ W	Garnett Rig #9	72-12-22 73-08-29	71.7 66.0	4 536.3 P & A
Gulf et al Hastings	45° 50′ 35″ N 64° 04′ 53″ W	Kenting Rig #11	75-06-11 75-08-07	80.2 76.7	2 939.5 P & A
Soquip-Acc et al Noel #1	5065736 N 444663 E	Regent Rig #22	75-07-18 75-08-09	70.0 65.5	1 447.8 P & A
Bras D'Or Anschutz #1 Antigonish	45° 39′ 40″ N 61° 52′ 30″ W	Simmons Rig #4	76-07-27 76-08-12	9.1	1 044.6 P & A
Chevron-Irving Malagawatch No. 1	45° 32′ 05″ N 60° 55′ 18″ W	Guthrie McLaren	79-10-31 79-11-23	8.03 3.06	948 P & A
Chevron-Irving Bras D'0r No. 2	45° 51′ 30″ N 61° 00′ 05″ W	Guthrie McLaren Rig #8	79-12-10 79-10-15	11.7 8.0	216 P & A
Chevron-Irving Scotsburn #2	43° 38′ 21.55″ N 63° 00′ 10.18″ W	Regent Rig #28	81-08-11 81-11-23	95.39 88.84	2 593 P & A